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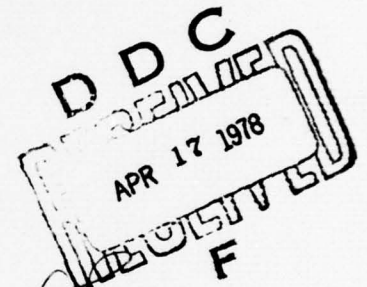
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Biological Effects of Nonionizing Electromagnetic Radiation

VOLUME II

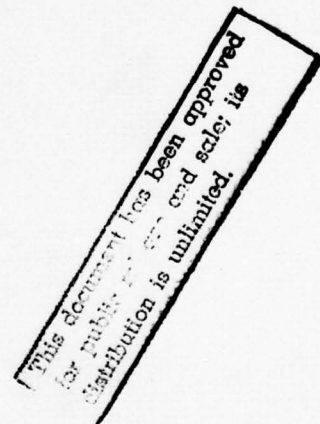
NUMBER 3

MARCH, 1978



A DIGEST OF CURRENT LITERATURE

A Quarterly Publication
Produced for
Office of Telecommunications Policy
and
United States Navy



"The views and conclusions contained in this documentation are those of the author and should not be interpreted as necessarily representing the officials' policies, either expressed or implied, of the Office of Telecommunications Policy or of the U.S. Navy."



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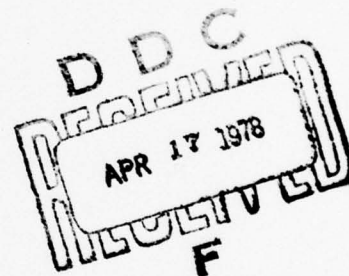
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**BIOLOGICAL EFFECTS
OF NONIONIZING ELECTROMAGNETIC RADIATION**

A Digest of Current Literature

**A Quarterly Publication
Produced for
Office of Telecommunications Policy
and
United States Navy**



*Literature Selected and Abstracted
by
Biomedical Group, Science Information Services Department*

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Elena P. Saboe, Production Manager, Editor

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BIOLOGICAL EFFECTS OF NONIONIZING ELECTROMAGNETIC RADIATION

March, 1978 Volume II, Number 3

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PREFACE

Biological Effects of Nonionizing Electromagnetic Radiation is a publication researched and prepared by the Franklin Institute Research Laboratories, Science Information Services Department, under a contract with the U.S. Navy and administered by the Office of Telecommunications Policy.

This digest serves as a vehicle through which current documentation of research highlights on the biological effects and health implications of nonionizing electromagnetic radiation (microwave and radiofrequency radiation) are compiled, condensed, and disseminated on a regular basis. *Biological Effects of Nonionizing Electromagnetic Radiation* is intended to be a highly useful current awareness tool for scientists engaged in research or related activities. The great number and diversity of relevant publications make imperative the availability of this service to persons whose work requires that they keep abreast of current developments in the field.

Biological Effects of Nonionizing Electromagnetic Radiation is published quarterly. The issues of Volume 11, and future volumes, will include materials received during the preceding three months. Each issue will include news items and announcements, a listing of meetings and conferences, abstracts of current literature, and a directory of current research. Materials for which full text is not available will be included as summary abstracts.

ABBREVIATIONS AND ACRONYMS

A, amp - ampere(s)	n - nano--
Å - angstrom(s)	NBS - National Bureau of Standards
BRH - Bureau of Radiological Health	NIH - National Institutes of Health
C - centigrade	NSF - National Science Foundation
cm - centimeter(s)	NIOSH - National Institute for
cps - cycles per second	Occupational Safety and Health
dB - decibel(s)	NTIS - National Technical Information
EPA - Environmental Protection Agency	Service
FDA - Food and Drug Administration	Oe - oersted(s)
g - gram(s)	OSHA - Occupational Safety and Health
G - Gauss	Administration
GHz - gigahertz	OTP - Office of Telecommunications
HEW - Health, Education, and Welfare	Policy
hr - hour	PHS - Public Health Service
Hz - hertz	rad - radiation absorbed dose
IEEE - Institute of Electronic and	R - roentgen(s)
Electrical Engineers	rpm - revolutions per minute
IMPI - International Microwave Power	sec - second(s)
Institute	USAFSAM - U.S. Air Force School of
IU - international unit(s)	Aerospace Medicine
J - joule(s)	USDA - U.S. Department of Agriculture
k - kilo--	UV - ultraviolet
l - liter(s)	V - volt(s)
m - meter(s)	VA - Veterans Administration
m - milli--	W - watt(s)
M - mega--	Wb - Weber(s)
mho - unit of measurement of	WHO - World Health Organization
conductivity	wk - week(s)
min - minute(s)	wt - weight
mo - month(s)	yr - year(s)

μ - micro--

NEWS ITEMS

IMPI PLANS BIOEFFECTS AND RADIATION SAFETY COURSE

A one-day intensive study course on microwave bioeffects and radiation safety, organized by IMPI and Radiation Protection Bureau, Health and Welfare Canada, has been scheduled for June 26, 1978 in Ottawa. The course is aimed at the health physicist, health inspector, physiologist, and radiologist who want to gain general knowledge about microwave radiation safety. The course curriculum will include basic definitions and concepts; quantification of hazardous microwave fields; biophysics--energy absorption, distribution, and interaction mechanisms; biologic and pathophysiologic effects of microwave exposure; comparative survey of microwave exposure standards; and control of microwave exposure in Canada. A panel discussion will conclude the course. Information may be obtained from Dr. M. A. Stuchly, Environmental Health Centre, Room 233, Ottawa, Ontario K1A 0L2, Canada.

IMPI Announcement

BRH CONDUCTS RADIOLOGIC HEALTH WORKSHOP

The BRH conducted a 2½-day workshop on radiologic health principles and issues for FDA's 55 consumer affairs officers during the Executive Director of Regional Operations' Annual Training Conference, November 14-18, 1977, in Rosslyn, Virginia. The workshop acquainted the consumer affairs officers with the basic mechanisms of ionizing, microwave, light, and sonic radiation; the effects of such radiation on the human body; the mandates to FDA on radiologic health; and the Bureau's regulatory and nonregulatory programs for protecting the public from unnecessary radiation exposure. Among the subjects addressed were the medical x-ray process, the roles of the radiologist and radiologic technologist, conventional x-ray equipment, computer tomography scanners, nuclear medicine, mammography, gonad shielding, the use of x rays and ultrasound in pregnancy, sunlamps, mercury vapor lamps, lasers, and microwave ovens. Attendees also received a three-volume manual, compiled by the Bureau's Division of Training and Medical Applications, emphasizing the Bureau's priority topics for consumer education in fiscal year 1978.

BRH Bull. 11(22): 3-4; 1977.

IEEE TO PUBLISH SPECIAL ISSUE: "MICROWAVES IN MEDICINE"

A special issue of the *IEEE Transactions on Microwave Theory and Techniques* on "Microwaves in Medicine, with Accent on the Application of Electromagnetics to Cancer Treatment" has been scheduled for publication in July 1978. Papers will emphasize the following areas: techniques for controlled local and general hyperthermia; applicator designs for producing hyperthermia; measurement of temperature distributions in tissue under microwave exposure;

rapid heating of frozen or refrigerated biologic media; noninvasive sensing of tissue properties and conditions; microwave thermography; noninvasive transfer of energy or information to implants; medically beneficial effects; effects on tumor cells, bacteria, viruses, and other organisms; and effects on blood flow, mass transport, and local tissue metabolism.

IEEE Trans. Microwave Theory Tech.
MTT25(3): 238; 1977.

NEW NBS RADIO FREQUENCY POWER METER AVAILABLE

A license and a design package to produce a new radio frequency (RF) power meter, recently developed and patented by the National Bureau of Standards (NBS), are now available. The meter, designated NBS Type IV RF Power Meter, was designed for use in automated measurement systems in which as many as 10 power meters would be under the control of a computer and would share a digital volt meter and digital-to-analogue connector. Like its predecessors, the NBS Types I and II meters, Type IV uses the direct current-RF substitution method for measuring power. Unlike Types I and II, it does not use a Wheatstone Bridge. The Type IV uses two operational amplifiers to automatically maintain equality between the resistance of a thermistor mount and the meter's internal standard resistor, to within one part in 10^5 . Doing away with the bridge and the use of 4-terminal resistor connections eliminates the lead-resistance errors inherent in thermistor-to-bridge connections. It also permits longer connecting lines between meter and thermistor. The package and a license under U.S. Patent No. 4,008,610 are available through NTIS, U.S. Department of Commerce, Washington, DC.

Microwave J. 20(12): 32; 1977.

CANCER RESEARCHERS REEVALUATE HYPERTHERMIA

Electrohyperthermia, once considered the tool of cancer quacks, is beginning to enjoy a renaissance in the treatment of cancer. When used in conjunction with chemotherapy, therapists have found that electrohyperthermia achieves better results than just application of chemotherapy alone. Electrohyperthermia pretreatment makes the cancer tissue more permeable to the drug. In addition, microwave-induced preheating enables lower doses to be administered, reducing the chances of complications caused by the larger dosage required without electrohyperthermia. Some researchers indicate that electrohyperthermia alone may be enough to kill cancer tissue. One medical renegade claims that in using an H-wave-polarized, 434-MHz source, the frequency of the radiofrequency (RF) wave itself, and not the heating induced by RF, is sufficient to cure certain types of cancer. To date, the real problem facing researchers is the inadequacy

NEWS ITEMS

of existing microwave diathermy equipment. One investigator, though, sees the day when better equipment will become available: "Flexibility is what's important now. After the researchers determine the best frequencies and power levels, a smaller, fixed-parameter type of system will surely result."

Microwaves 16(9): 22-24; 1977.

MICROWAVES BOOST WHEAT CROP YIELD

Researchers in India are discovering that microwave irradiation can help improve diseased wheat seeds before planting and increase yield once the crop is sown. Exposure to microwave energy improves the process of seed mutation and thereby boosts the crop yield. Seeds are irradiated in a simple matched waveguide load, suspended on electrically transparent foam in the maximum E-field region. Crops are irradiated by means of high-gain, low-sidelobe antennas. By irradiating the seeds at a specific molecular resonant frequency, energy absorption is increased, speeding the mutation process. "One of the main aims is to improve the protein content of wheat," explains Chinmoy Das Gupta, Assistant Professor of electrical engineering at the Indian Institute of Technology, Kanpur. "Once the characteristic resonance frequency of isolated protein molecule is known, the crops will be subjected to irradiation centered on this resonant frequency."

Microwaves 16(9): 12, 18; 1977.

BOOK REVIEWS MICROWAVE RISKS

In *The Zapping of America: Microwaves, Their Deadly Risk, and the Cover-up*, Paul Brodeur, a staff writer on *The New Yorker*, examines the physiologic effects and environmental impact of microwave radiation. This 343-page volume is published by W. W. Norton, New York.

URSI CALLS FOR PAPERS FOR ELECTROMAGNETIC BIOEFFECTS SYMPOSIUM

An open symposium on Biological Effects of Electromagnetic Waves will be held as part of the 19th General Assembly of the International Union of Radio Science in Helsinki, Finland, August 1-8, 1978. The symposium will feature six or seven half-day sessions on the following and other related areas: theoretical and experimental dosimetry and field measurements, instrumentation, mechanisms of interaction with biologic systems, hyperthermia and biomedical applications, behavioral and central nervous system effects, philosophy of standards, and international cooperative studies. The deadline for submission of papers is April 15, 1978. Communications may be

Biological Effects of Nonionizing Electromagnetic Radiation 11(3), March 1978

addressed to Professor A. W. Guy, Dept. of Rehabilitative Medicine, CC-814 University Hospital RJ-30, Univ. of Washington School Medicine, Seattle, Washington 98195.

International Union of Radio Science Announcement

NARDA DEVELOPS MICROWAVE BRIDGE

A precision matched microwave bridge has been developed by the Narda Microwave Corporation with a 35 dB directivity for the entire frequency range from 2 to 18 GHz or more and with all ports well-matched for minimum contribution to measurement error. The bridge performs the same function as a high directivity coupler, and the two devices may be used interchangeably in reflectometer and network analyzer applications.

Narda Probe 9(2): 1-8; 1977.

RADIO ENERGY HEALING SOCIETY FORMED

Although the effects of magnetic and electric fields in medicine and biology are little understood, interest in the benefits, dangers, and contraindications of electromagnetic energy associated with clinical application is rising. At a meeting at St. Bartholomew's Hospital, London, researchers last year decided to form "The Society for the Study of Electrical Phenomenon in Living Systems." Presentations at that meeting included a paper entitled "Callus Formation by Electret (see Current Literature 5281) and a discussion of the use of pulsed radio frequency energy for reducing bruising and edema following surgery. The society plans to hold two meetings each year and restrict membership to those actively working in the field.

J. Med. Eng. 1(5): 291-292; 1977.

ELECTRIC STIMULATION IMPROVES HONEY YIELD

Researchers in the Soviet Union have reported improved bee colony development by applying an electrical charge for short durations. The swarm is placed between two metal plates, 50 cm apart, and a potential of 20 kV with a frequency of 200-1,000 Hz is applied. A variable electric field is established in the order of 400 V/cm, which activates the bees. The time for one session is 5-10 min and the interval between sessions in the spring/summer session is 5-6 days and in the autumn, 1-3 days. The operations in spring and summer ensure the development of the colony to the start of nectar flow and in autumn ensure growth of young bees going into hibernation. In one experiment, bees were treated from the start of June to mid-July. Every 12 days a check was made. The colony was found to gather 50% more honey and to reproduce at a rate of 40% more than non-treated bees. Treatment

at the end of August through early September (every 1-2 days for 2 wk) ensured reproduction increase by a factor of two.

Soviet Inventions Illustrated (Y42): 3; 1977.

ELECTRICAL SAFETY COLLOQUIUM SCHEDULED

The International Section for the Prevention of Occupational Risks due to Electricity of the International Social Security Association will hold a colloquium concerning safety for the electrical expert with emphasis on basic and advanced training. Details on the colloquium, to be held in Lucerne, Switzerland, on May 17-19, 1978, may be obtained from the Berufsgenossenschaft der Feinmechanik und Elektrotechnik, Oberlaender Ufer 130, D-5000 Koeln 51, West Germany.

Lancet 2(8047): 1092; 1977.

MICROWAVE DIAGNOSIS AND THERAPY WORKSHOP SCHEDULED

A one-day workshop on Diagnosis and Therapy using Microwaves will be held shortly after the Eighth European Microwave Conference scheduled for September 4-8, 1978, in Paris. The conference itself will include presentations on the Biological Effects and Medical Applications of Microwaves. Details on both the workshop and the conference may be obtained from Professor E. Constant, 8th EuMC Conference Chairman, Centre Hyperfréquence et Semiconducteurs, Université des Sciences et Techniques, BP 36, 59650 Villeneuve d'Ascq, France.

8th European Microwave Conference Announcement

ELECTRIC FIELD EFFECTS RESEARCH EXPANDS

"If electric fields can cause biological effects, it appears that they will be subtle, possibly elusive, and extremely difficult to identify," according to Dr. Harry Kornberg, Environmental Assessment Department of the Electric Power Research Institute (EPRI). Kornberg notes that research on the possible effects of electric fields from high-voltage transmission lines began in the 1960s. Public awareness increased in the late 1970s, triggered primarily by reports from the Soviet Union describing medical complaints from switchyard workers exposed to high-voltage gradients for long periods. A similar experience occurred in Spain, where five of eight switchyard workers, transferred to a new 500-kV power station, reported headaches, fatigue, and loss of appetite. However, examinations of line workers in Canada, England, France, West Germany, Italy, and the U.S. have shown no adverse biologic effects. "No experiment thus far has clearly established that electric fields even 20 times as high as those encountered under 765-kV

transmission lines can cause a biological effect of significance," states Kornberg. A number of studies are under way both in the U.S. and in other countries to pinpoint electric field effects. The EPRI is sponsoring research amounting to \$2 million/yr in the area and the Energy Research and Development Agency (ERDA) is sponsoring \$1 million/yr. According to Kornberg, both EPRI and ERDA are optimistic that some definitive answers on electric field effects will be forthcoming within the next few years.

Mech. Eng. 99(11): 20-21; 1977.

BRH REVIEWS RADIATION CONTROL EFFORTS

In a brief report entitled "A Look at FDA's Program to Protect the American Consumer from Radiation," the BRH provides a brief overview of FDA's major regulatory and voluntary effort in the area of radiation control and examines the impact of the agency's programs to eliminate unproductive radiation exposure to the consumer. The report concludes with a summary of present and future concerns about newly-emerging radiation-emitting products and uses and the potential public health problems that they may engender.

HEW Publication (FDA) 77-8032; 18 pp.; April, 1977.

ENVIRONMENTAL IMPACT OF ELECTRIC FIELDS STUDIED

Under contract to the Electric Power Research Institute (EPRI), Westinghouse Advanced Systems Technology, in conjunction with the Pennsylvania State University, is performing a research project to study the effects of electric fields on plants and animals typically found in the vicinity of power transmission lines. The contract is a portion of EPRI's comprehensive program committed to determining the environmental impact of the electric fields produced by extremely high voltage and ultra high voltage transmission lines. The research team coordinates the skills of Westinghouse engineers familiar with electric utility operations and instrumentation techniques with the work of biologists from the Pennsylvania State University specializing in the practical and theoretic aspects of plant and animal growth and behavior. Biologic studies that have and will be performed include effects studies monitoring hatching time, weight, and activity of developing avian embryos; growth, activity, electrocardiographic and electroencephalographic responses of young chicks; and the capability of field detection by domestic pigeons. Biologic effects studies on several species of green plants are also being performed.

J. Microwave Power 12(1): 42; 1977.

ITEMS FROM THE COMMERCE BUSINESS DAILY

□ CONTINUATION OF RESEARCH ON MICROWAVES,
ELECTROMAGNETIC THEORY AND INFORMATION PROCESSES.

The Directorate of Procurement, Air Force Office of Scientific Research, Bolling Air Force Base, Washington, DC, has contracted with the Polytechnic Institute of New York, Brooklyn for the above study. (November 2, 1977)

□ FURTHER RESEARCH DESIGNED TO ASSESS THE
EFFECTS OF CHRONIC, LOW-LEVEL MICROWAVE EXPOSURE
ON THE HEMATOPOIETIC SYSTEM OF MICE.

The Office of Naval Research, Arlington, Virginia, is negotiating with Battelle Memorial Institute, Pacific Northwest Laboratories Division, Richland, Washington for the above study. (November 17, 1977)

□ BIOLOGICAL CONSEQUENCES OF PULSED VS
CONTINUOUS WAVE RADIOFREQUENCY RADIATION STUDY.

The Directorate of R & D Procurement, Wright-Patterson Air Force Base, Ohio, has contracted with Georgia Tech Research Institute, Georgia Institute of Technology, Atlanta, Georgia for the above study. (December 2, 1977)

□ RESEARCH ON THE TEMPORAL RELATIONSHIP
BETWEEN THE ELF FIELD FROM THE PROJECT SEAFARER
WISCONSIN TEST FACILITY AND PATH DEVIATIONS BY
MIGRATING BIRDS.

The Office of Naval Research, Arlington, Virginia, has contracted with Marine Biological Laboratory, Woods Hole, Massachusetts for the above study. (December 19, 1977)

□ RESEARCH ON THE EFFECT OF 60 Hz FIELDS ON THE
MAMMALIAN CENTRAL NERVOUS SYSTEM.

The Office of Naval Research, Arlington, Virginia, has contracted with the Regents of the University of California, Los Angeles for the above study. (January 5, 1978)

□ CONTINUATION OF NECESSARY SERVICES TO
COORDINATE FEDERAL/STATE RADIATION CONTROL
ACTIVITIES AND ASSISTANCE IN SOLVING RADIATION
CONTROL PROBLEMS.

The FDA, PHS, HEW, Rockville, Maryland, is negotiating with the Conference of Radiation Control Program Directors, Inc. for the above study. (January 16, 1978)

NON-IONIZING RADIATION: EUROPEAN HIGHLIGHTS

Dr. Paul D. Gillespie, Managing Director

The Franklin Institute, GmbH, Munich, Federal Republic of Germany

An investigation of currently funded research programs in the United Kingdom reveals that the only study of the bioeffects of non-ionizing radiation is being conducted at the Physics Department of Queen Elizabeth College, London University. This project, sponsored by the Medical Research Council, is under the direction of Dr. E. H. Grant. Dr. Grant, a biophysicist, defines the thrust of the study as an effort to provide information that will lead to recommendations for establishing maximum permissible microwave exposure levels as a function of radiation frequency. Power-patterned after the U.S. exposure limits, current British limits are quoted in units of incident radiation, and they employ the same value, 10 mW/cm². The concept of a frequency factor in establishing radiation exposure limits is particularly interesting. While there are no cases where it has been clearly and unambiguously established that biologic injury to man has been observed resulting from microwave

radiation at incident power levels of 10 mW/cm² or below, furnace workers and glassblowers without eye protection experience the development of cataracts. While the cataracts were all attributed officially to infrared radiation exposure, the low frequency end of the infrared region merges with the high frequency end of the microwave region. Further, various tissue damages have been reported in laboratory animals at microwave incident power levels one full order of magnitude lower than presently accepted as permissible. Another compelling reason to consider the frequency factor in the establishment of maximum permissible limits is that the ability of various tissues to absorb energy is frequency dependent.

Dr. Grant reports that they are fifteen months into what is seen initially as a three-year project. Their accomplishments to this point, he continues, have been twofold: first, the construction of devices designed to measure electrical permittivity and conductivity of

human eye lens tissue in the 100 MHz to 10 GHz frequency range, and second, the conduction of irradiation experiments upon lens. To date, the experimental data have convinced Dr. Grant that the research will produce sufficient evidence in two year's time to support a strong case for establishing exposure limits for non-ionizing radiation based on frequency dependence. Dr. Grant reports that their findings also show that the bound water of lens tissue absorbs more readily than unbound water in tissues.

Parallel to the above work, Dr. Grant's group is conducting microwave hyperthermia experiments.

In connection with Dr. Grant's work on establishing frequency factors in exposure limit determinations, it is interesting to note that the effort of the Commission of the European Communities' Working Group to set the ground rules for a common nine-nation policy for estab-

lishing exposure limits for nonionizing radiation has now been delayed for a year. According to Dr. Hans Eriskat of the European Commission, the report of the Working Group, which was due in the Fall of 1977, is not expected until the last quarter of 1978. Eriskat indicates that for a variety of reasons, including the frequency factor argument, no agreement could be reached in the Working Group, which is composed of experts in the field of biological effects of nonionizing radiation from all nine of the member states. Although the group meets regularly, as yet there is no pressure from individual nations for action.

(Note: Direct inquiries regarding "European Highlights" care of the Editor, *Biological Effects of Nonionizing Electromagnetic Radiation*, Science Information Services, Franklin Institute Research Labs., The Benjamin Franklin Parkway, Philadelphia, PA 19103)

MEETINGS AND CONFERENCES

THIRD INTERNATIONAL SUB-MILLIMETER WAVES CONFERENCE-1978

Date: March 29-April 1, 1978
Place: Guildford, England: Univ. Surrey
Sponsor: Inst. Physics, in collaboration with Inst. of Electrical Engineers, Inst. Electrical & Electronics Engineers, Inst. Electronic and Radio Engineers
Requests for Information: Mtgs. Officer, Inst. Physics, 47 Belgrave Sq., London, SW1X 8QX, England

ELECTROMAGNETIC COMPATIBILITY CONFERENCE

Date: April 4-7, 1978
Place: Guildford, England: Univ. Surrey
Sponsor: Inst. Electronic and Radio Engineers in association with Inst. Electrical & Electronics Engineers, Inst. Quality Assurance, Inst. Marine Engineers, Royal Aeronautical Society
Requests for Information: P. M. Elliott, IERE

AMERICAN OCCUPATIONAL HEALTH CONFERENCE

Date: April 9-14, 1978
Place: New Orleans, LA: Fairmont
Sponsor: American Occupational Medical Assoc., American Assoc. Occupational Health Nurses
Requests for Information: H. N. Schulz, AOMA, 150 N. Wacker Dr., Chicago, IL 60606

FEDERATION OF AMERICAN SOCIETIES FOR EXPERIMENTAL BIOLOGY: Annual Meeting

Date: April 9-14, 1978
Place: Atlantic City, NJ
Sponsor: Federation of American Societies for Experimental Biology (FASEB)
Requests for Information: Mrs. H. B. Lemp, FASEB, Off. of Scientific Meetings, 9650 Rockville Pike, Bethesda, MD 20014

INTERNATIONAL CONFERENCE ON RECENT ADVANCES IN BIOMEDICAL ENGINEERING

Date: April 17-21, 1978
Place: Sheffield, England: Univ. Sheffield
Sponsor: Biological Engineering Society (BES)
Requests for Information: Dr. K. Copeland, BES, Dept. Biophysics, Univ. College London, Gower St., London WC1E 6BT, England

INTERNATIONAL MAGNETICS CONFERENCE (INTERMAG)

Date: May 9-12, 1978
Place: Florence, Italy
Sponsor: Inst. Electrical & Electronics Engineers--Magnetics Group; Italian Physical Soc.; Italian Assoc. Electrical & Electronics Engineers
Requests for Information: J. Suozzi, Bell Telephone Labs., Whippany, NJ 07981

USNC-URSI/IEEE AP-S (Radio Science/Antennas and Propagation) Meeting

Date: May 15-19, 1978
Place: Washington, DC
Sponsor: International Union Radio Science-U.S. National Committee (USNC-URSI); Inst. Electrical & Electronics Engineers (IEEE)--Antennas & Propagation Society
Requests for Information: G. Hyde, Propagation Studies Dept., Comsat Labs, Box 115, Clarksburg, MD 20734

NINTH INTERNATIONAL CONGRESS OF THE SOCIETE FRANCAISE DE RADIOPROTECTION: Risks associated with the utilization of nonionizing radiations

Date: May 22-26, 1978
Place: Chateau de Naninville-les-Roches near Paris, France
Sponsor: Societe Francaise de Radioprotection
Requests for Information: M. Regis Marchand, Congress President, DSC-18 Rue Ernest-Cognacq, 92300-Levallois-Perret, France

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS: Annual Convention (ELECTRO/78)

Date: May 23-25, 1978
Place: Boston, MA: Sheraton Boston & Hynes Auditorium
Sponsor: Inst. Electrical & Electronic Engineers, Electronic Reps. Assoc.
Requests for Information: W. C. Weber, Jr., C/O IEEE Boston Office, 31 Channing St., Newton, MA 02158

CONFERENCE ON PRECISION ELECTROMAGNETIC MEASUREMENTS

Date: June 26-29, 1978
Place: Ottawa, Canada: Government Conf. Cent.
Sponsor: Inst. Electrical & Electronics Engineers--Instrumentation and Measurement Group; National Bureau Standards; International Union of Radio Science-U.S. National Committee

MEETINGS AND CONFERENCES

Biological Effects of Nonionizing Electromagnetic Radiation II(3), March 1978

Requests for Information: K. Charbonneau,
Executive Secretary, C/O National Research
Council of Canada, Ottawa, Canada
K1A 0R6

IEEE MTT-S INTERNATIONAL MICROWAVE SYMPOSIUM

Date: June 27-29, 1978
Place: Ottawa, Canada: Chateau Laurier Hotel
Sponsor: Inst. Electrical & Electronics
Engineers (Microwave Theory & Technique)
Requests for Information: S. J. Kubina,
Publicity Chairman, Electrical Engineering
Dept., Concordia Univ., 7141 Sherbrooke St. W.
Montreal, Quebec H4B 1R6

1978 SYMPOSIUM ON ELECTROMAGNETIC FIELDS IN BIOLOGICAL SYSTEMS

Date: June 27-30, 1978
Place: Ottawa, Canada: Holiday Inn (Centre)
Sponsor: Microwave Theory & Techniques Society,
Inst. Electrical & Electronic Engineers, Inter-
national Microwave Power Inst. with the co-
operation of U.S. Committee for URSI and
Canadian Commission A of URSI
Requests for Information: M. H. Repacholl,
Local Arrangements Chairman, Dept. National
Health & Welfare, Environmental Health Centre,
Room 233, Tunney's Pasture, Ottawa, Canada
K1A 0L2

IMPI MICROWAVE POWER SYMPOSIUM: 1978

Date: June 28-30, 1978
Place: Ottawa, Canada: Chateau Laurier Hotel
Sponsor: International Microwave Power
Institute (IMPI)
Requests for Information: W. Wyslouzil, Local
Arrangements Chairman, Electrical Engineering
Div., National Research Council of Canada,
Ottawa, Canada K1A 0R8

OPEN SYMPOSIUM ON BIOLOGICAL EFFECTS OF ELECTROMAGNETIC WAVES

Date: August 1-8, 1978
Place: Helsinki, Finland
Sponsor: International Radiation Protection
Association (IRPA) and Commissions A & B
Requests for Information: Professor A. W.
Guy, Dept. Rehabilitation Medicine, CC-814
Univ. Hospital RJ-30, Univ. Washington
School of Medicine, Seattle, Washington
98195

EIGHTH EUROPEAN MICROWAVE CONFERENCE

Date: September 4-8, 1978
Place: Paris, France: Hotel Meridien
Sponsor: Societe des Electriciens, des Elec-
triciens et Radioelectriciens (Groupement
des Industries Electriques)
Requests for Information: Professor E. Constant,
Conference Chairman, Centre Hyperfrequences
et Semiconducteurs, Universite des Sciences
et Techniques, BP 36, 59650, Villeneuve d'Ascq,
France

AMERICAN ACADEMY OF OCCUPATIONAL MEDICINE: Thirtieth Annual Meeting

Date: September 20-22, 1978
Place: Williamsburg, VA
Sponsor: American Academy of Occupational
Medicine (AAOM)
Requests for Information: AAOM, 150 N.
Wacker Dr., Chicago, IL 60606

WESTERN OCCUPATIONAL HEALTH CONFERENCE

Date: October 12-14, 1978
Place: Los Angeles, CA: Hyatt Regency Hotel
Sponsor: American Industrial Hygiene Assoc.,
Health Physics Society; Western Occupational
Medical Assoc. (WOMA); Western Assoc. Indus-
trial Nurses; American Society Safety Engi-
neers
Requests for Information: B. H. Bravinder,
WOMA

ENGINEERING IN MEDICINE & BIOLOGY: Thirty-first Annual Conference

Date: November 4-8, 1978
Place: Atlanta, GA: Marriott
Sponsor: Alliance for Engineering in Medicine
and Biology (AEMB)
Requests for Information: Mrs. P. I. Horner,
AEMB

INTERNATIONAL UNION OF RADIO SCIENCE-- U.S. NATIONAL COMMITTEE MEETING

Date: November 5-10, 1978
Place: Boulder, CO
Sponsor: International Union of Radio Sci-
ence--U.S. National Committee
Requests for Information: S. W. Maley,
Dept. E, Univ. Colorado, Boulder, CO 80309

CURRENT RESEARCH

0209 ELECTRON SPIN RESONANCE STUDIES OF EFFECTS OF 1.0, 2.45, AND 9 GHZ EMR ON CELL MEMBRANES. Fisher, H. L. (Bioengineering Branch, Environmental Protection Agency, Experimental Biology Div., Durham, NC 27111).

Expanding uses of nonionizing electromagnetic radiation require adequate safety and protective measures. To apply these measures, the biologic and biophysical effects of the radiation must be understood. Although acute exposures and effects have been investigated, studies of chronic low-level exposures are lacking due to the experimental difficulties. Two approaches to this problem are to study the final result or biologic effect or to study the initial biophysical processes occurring upon radiation exposure. This project will examine the erythrocyte plasma membrane following exposure. This membrane has been well-characterized, and damage to it from ionizing radiation and other insults has been tabulated. In this study, the presence of temporary or permanent structural changes in the membrane at the molecular levels will be investigated using spin labels. These changes, if present, will be correlated with accumulated doses and dose rate. (10/76-9/77)

Supporting Agency:EPA

0210 EFFECTS OF CHRONIC, FRACTIONATED EXPOSURE TO MICROWAVES ON LEARNING AND MEMORY OF RATS. Gage, M. I. (Neurobiology Branch, Environmental Protection Agency, Health Effects Res. Lab., Durham, NC 27711).

Rats, trained to perform a task of alternating between two levers a fixed number of times for food reinforcement, are being exposed to low levels of 2,450 MHz microwaves. After training, the rats will be exposed to a power density of 10 mW/cm² 3 nights/wk for 3 or 6 mo, to determine whether chronic exposures to microwaves altered learned behavior. The rats will then be given single exposures to various power densities of 2,450 MHz radiation to determine the threshold level that would alter the performance of the learned task. Currently, chronic exposures have been terminated and single exposures are nearing completion; data analysis is in progress. (10/76-9/77)

Supporting Agency:EPA

0211 FERROMAGNETIC SILICONE VASCULAR OCCLUSION IN NEOPLASMS. Rand, R. W.; Poe, N.; Snow, H.; DiIullo, M.; Snyder, M.; Scholten, S. (Univ. California, Sch. Medicine, 405 Hilgard Ave., Los Angeles, CA 90024).

Ferrosilicone occlusion research for cerebral aneurysms, vascular malformations, and hypervascular tumors will be continued along the same lines as in the past. Different types of iron compounds will be tested in animals to study which, if any, has more

ability to be effective by an external electromagnetic field. Work will be closely carried out with the scientists at the Jet Propulsion Laboratory in Pasadena who are in the process of constructing appropriate electronic instrumentation to carry out the basic research. Results of in vivo experiments in dogs and bench experiments in the laboratory indicate that there is great promise if the ferromagnetic silicone material can be significantly influenced in electromagnetic fields. The ability to produce intense necrosis of tissue, especially cancerous tissue, in a very localized, selective manner will be enhanced. (2/77-1/78)

Supporting Agency:HEW, PHS, NIH, NCI

0212 THE THERAPEUTIC RATIO AND EXPERIMENTAL RADIO THERAPY. Phillips, T. L.; Fu, K. K.; Goldstein, L. S.; Begg, A.; Baker, R. J.; Kane, L. (Univ. California, Sch. Medicine, 551 Parnassus Ave., San Francisco, CA 94122).

Quantitative systems, which measure normal tissue damage and tumor response in the mouse, will be applied to evaluate factors and agents that modify radiation response in ways favorable to the therapeutic ratio. Fractionation, hyperthermia, cancer chemotherapeutic agents, and heavy particle irradiation potentially increase tumor response, a lesser increase in normal tumor response, and therefore increase the therapeutic ratio. Normal tissue endpoints will be measured in the brain, lung, esophagus, kidney, small intestine, skin and bone marrow; tumor response will be measured in the EMT6 carcinoma assayed as a solid tumor, as small metastases, and in vitro. Hyperthermia will be generated by a specially designed microwave apparatus and irradiation chamber for segmental heating of mice. Drugs investigated include adriamycin, actinomycin, BCNU, cyclophosphamide, and bleomycin. High linear energy transfer (LET) radiations under investigation include 15 MeV neutrons, helium ions, and neon ions, as well as carbon and argon. (5/77-4/78)

Supporting Agency:HEW, PHS, NIH, NCI

0213 HYPERTHERMIA AND RADIATION: X-RAYS VS FAST NEUTRONS. Nagle, W. A.; Moss, A. J.; Baker, M. L.; Prior, R. M.; Straub, K. D. (Univ. Arkansas, Sch. Medicine, 4301 W. Markham St., Little Rock, AR 72201).

An in-depth study of the interaction of 1) agents that cause heating (thermal heat, ultrasound, and microwaves) and 2) ionizing radiations of both low (250 kV X-rays) and high (fast neutrons) linear energy transfer (LET) will be performed. The use of hyperthermia in combination with low LET radiation to simulate high LET will be evaluated. Cultured cells of three different mammalian lines will be used; cell populations will be synchronized where appropriate. The experiments will be performed under conditions of hypoxia as well as normal oxygenation. Both cellular (proliferative

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integrity) and molecular (production and repair of DNA single strand breaks) will be measured. These data will help to establish a biologic base from which rational clinical trials can be formulated. (7/77-6/78)

Supporting Agency:HEW, PHS, NIH, NCI

0214 RADIATION AND HYPERTHERMIC CANCER THERAPY. Robinson, J. E. (Univ. Maryland, Sch. Medicine, 1420 N. Charles St., Baltimore, MD 21201).

The action of hyperthermia alone and in combination with ionizing radiation will be investigated to answer current questions on the use of this combined modality in cancer therapy. Laboratory data show that radiation sensitivity is markedly enhanced at elevated temperatures. The objectives of research, which are aimed at clinical applicability, are: (1) to develop and evaluate a technique of microwave heating of animals and animal tumor systems that are clinically relevant; (2) to assess the relative thermal sensitivities and radiosensitivities of normal and malignant tissues under microwave-induced hyperthermic conditions and (3) to compare results with existing experimental data in which elevated temperatures were obtained by tumor immersion in water baths. Localized and generalized hyperthermia, as an adjunct to radiotherapy, offers the potential of further increasing rates of local tumor control. (7/77-6/78)

Supporting Agency:HEW, PHS, NIH, NCI

0215 GENETIC AND CELLULAR EFFECTS OF MICROWAVE RADIATION. Dutta, S. K.; Brusick, D.; Blackman, C. (Dept. Botany, Howard Univ. Sch. Liberal Arts, 2400 6th St. N.W., Washington, DC 20001).

To determine whether microwave radiation can affect normal cellular processes associated with the utilization of genetic information, a battery of cellular systems having a variety of genetic structures and functions will be used to distinguish between perturbations caused solely by temperature rise and those caused by other mechanisms. Several genetic systems have been established, standardized, and characterized over a range of environmental temperatures. These include strains of *Saccharomyces cerevisiae*, *Salmonella typhimurium*, and *Escherichia coli*. These cell types have been exposed to pulsed radiation between 8.6 and 9.6 GHz, and the data are being analyzed. (10/76-9/77)

Supporting Agency:EPA

0216 BEHAVIORAL AND EEG RESPONSES OF MONKEYS EXPOSED IN UTERO TO LOW LEVEL EMR. Kaplan, J. N.; Polson, P. (Dept. Psychology, Stanford Res. Inst., 333 Ravenswood Ave., Menlo Park, CA 94025).

Teratogenesis as well as certain behavioral, bio-

chemical, and electroencephalographic parameters will be evaluated in pregnant squirrel monkeys exposed to chronic low-level microwave irradiation throughout gestation. The behavioral, biochemical, and electroencephalographic measures to be monitored are those likely to be sensitive to stress-related conditions. In addition, similar measurements will be made on half of the offspring, who will be exposed chronically for 12 mo after birth, and on their mothers, who will continue on the exposure regimen for 6 mo after birth. Whole-body microwave exposures of unrestrained animals (pregnant females, mothers, offspring) will be conducted approximately 0.1, 1.0, and 10 mW/cm² at 2,450 MHz for 3 hr/day, 5 days/wk in multimode, modestirred microwave cavities, each containing a dielectric cage. This permits whole-body irradiation of an unrestrained monkey in a modulated, pulsed radio frequency field. Currently, pregnant females are being exposed to the microwaves. Offspring have been or are being born, and offspring will continue to be exposed and examined for various indicators of behavioral development. (10/76-9/77)

Supporting Agency:EPA

0217 DEFINE SPECIFIC ABSORPTION FREQUENCIES OF NON-IONIZING ELECTROMAGNETIC RADIATION IN BIOLOGICAL SYSTEMS. Blackman, C. F.; Weil, C. M.; Allis, J. W.; Elder, J. A. (Environmental Protection Agency, Experimental Biology Div., Durham, NC 27111).

To study the interactions of nonionizing electromagnetic radiation with biologic systems, a microwave spectrometer will be constructed and used to determine the frequencies in the microwave radiation spectrum that interact with molecules, sub-cellular systems, cells, and tissues. Initial tests with a simplified spectrometer demonstrated the need for a more elaborate system utilizing a dual beam method. A prototype instrument is being constructed. (10/76-9/77)

Supporting Agency:EPA

0218 ENHANCEMENT OF CHEMOTHERAPEUTIC AGENTS BY LOCAL TUMOR HYPERTHERMIA. Magin, R. L.; Adamson, R. H.; Cysyk, R. L. (Chemical Pharmacology Lab., U.S. Dept. Health, Education, Welfare, Natl. Cancer Inst., Bethesda, MD 20014).

The feasibility of enhancing the effectiveness of chemotherapeutic agents and decreasing their toxicity will be investigated by using local tumor hyperthermia to augment drug therapy. Microwave radiation (2,450 MHz) will be applied locally to small mouse tumors to produce local tumor hyperthermia (43 C). The effect of drugs on tumor growth and animal survival will be determined in animals with locally hyperthermic tumors. Tumor drug uptake, DNA/drug binding, and DNA repair enzyme inactivation will be investigated. Solid tumors to be studied include subcutaneously implanted mammary, Lewis lung, B-16 melanoma, colon, and glioma in mice.

A microwave system for the production of a controlled localized tumor hyperthermia in four mice simultaneously has been assembled. Intratumor temperature uniformity of $\pm .5$ C has been achieved. Preliminary studies with adriamycin are being conducted. (10/76-9/77)

Supporting Agency:HEW, PHS, NIH, NCI.

- 0219 EFFECTS OF CHRONIC MICROWAVE EXPOSURE ON IMMUNE DEFENSE MECHANISMS. Liddle, C. G.; Smialowicz, R. J. (Environmental Protection Agency, Experimental Biology Div., Durham, NC 27111).

The objective of this project is to examine the effects of repeated low-level microwave exposure on immunologic responses in rats and mice. Rats will be exposed daily to low levels of 2,450, 425, or 100 MHz radiation under controlled environmental conditions throughout gestation and early postnatal life. In one group of studies, the metabolic and proliferative capacity of lymphocytes obtained from irradiated animals will be evaluated by measuring the incorporation of radioactive precursors into DNA and/or RNA following addition of mitogens that stimulate subpopulations of lymphocytes. In other studies, the circulatory antibody response will be measured after immunization against *Streptococcus pneumoniae*. Circulatory antibody response will also be assayed in mice exposed during antibody production. In an earlier study it was found that microwave (2,450 MHz) irradiation of cultured mouse lymphocytes did not alter the proliferative potential of either T or B lymphocytes. Preliminary studies on rats chronically exposed to 425 and 2,450 MHz suggested changes in lymphocyte function, including DNA synthetic capacity; apparent increases in circulating antibody titers were noted at 2,450 MHz. Results of a preliminary study with mice exposed to 9 GHz during antibody production indicated an increased antibody titer. More extensive chronic studies with rats are underway at 425 and 2,450 MHz, and similar studies are planned at 100 MHz. Exposure of additional mice during antibody production is planned. (10/76-9/77)

Supporting Agency:EPA

- 0220 EFFECTS OF ACUTE AND CHRONIC EXPOSURE TO PULSED UHF RADIATION ON MONKEYS' MEMORIES. Gage, M. I. (Neurobiology Branch, Environmental Protection Agency, Health Effects Res. Lab., Durham, NC 27711).

Effects of low level electromagnetic radiation on the learning and memory ability of primates will be studied. Specifically, the ability of monkeys to learn and to repeatedly perform a visual discrimination task requiring the choice of a visual pattern that matches a sample stimulus will be performed. The animals will then be exposed to various power densities of microwaves to determine threshold levels for producing changes in behavioral performance. Finally the monkeys will be exposed

to microwaves at threshold effect levels for extended periods to determine whether performance deteriorates further. To date, apparatus is being constructed, and animals have been obtained. During the next year the monkeys will be trained, and threshold levels will be determined. (10/76-9/77)

Supporting Agency:EPA

- 0221 INTERACTIONS OF AMPLITUDE MODULATED (AM) NON-IONIZING EMR WITH BIOLOGICAL SYSTEMS. Elder, J. A. (Environmental Protection Agency, Health Effects Res. Lab., Durham, NC 27711).

The Ca_2 ion efflux in brain tissues exposed to microwave radiation amplitude modulated at 0-32 Hz will be examined. Brains from 2- to 7-day-old chicks will be labeled in vitro with $^{45}\text{Ca}_2$ and exposed to 147 MHz microwave radiation amplitude modulated at 0, 8, 16, 24, and 32 Hz. The samples will be analyzed for changes in Ca_2 ion efflux as a function of both carrier wave and amplitude modulation frequencies, power density, pH, and other physiologic parameters. A Crawford Cell irradiation chamber has been constructed, and preliminary experiments are underway. (10-76-9/77)

Supporting Agency:EPA

- 0222 NEUROPHYSIOLOGIC AND BEHAVIORAL RESPONSES OF ANIMALS REPEATEDLY EXPOSED TO LOW LEVEL EMR. Reiter, L. W.; Gray, L. E. (Environmental Protection Agency, Health Effects Res. Lab., Durham, NC 27711).

The effects of 100-MHz electromagnetic radiation on central nervous system development in the rat will be studied. Animals will be exposed both pre- and postnatally to nonionizing radiation. Neurologic (reflex) and behavioral (spontaneous motor activity and social behavior) development will be measured. The results should provide data helpful in assessing nervous system effects of chronic exposure to microwaves. (10/76-9/77)

Supporting Agency:EPA

- 0223 EFFECTS OF CHRONIC MICROWAVE EXPOSURE ON IMMUNE DEFENSE MECHANISMS. Huang, V. T. (Dept. Internal Medicine, Duke Univ. Sch. Medicine, Box 3711, Durham, NC 27706).

The effects of microwave radiation on the immune system and chromosomes in animals will be determined, and the minimum radiation exposure that causes detectable effects will be defined. Experimental animals will be exposed to microwave frequencies of 500, 2,450, and/or 9,000 MHz at average power densities below 30 mW/cm^2 . Immunocompetent cells from these animals will be studied for morphologic and biochemical changes including lymphoblastoid transformation; mitotic figures; and DNA, RNA, and protein synthesis. In addition, peripheral lympho-

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cytes and bone marrow cells from rats and mice chronically exposed to microwaves will be examined by both standard immunologic and cytogenetic techniques. (10/76-9/77)

Supporting Agency:EPA

0224 ABSORPTION CHARACTERISTICS OF PROLATE SPHEROIDAL MODEL OF MAN AND ANIMALS AT AND NEAR RESONANCE FREQUENCY. Tripathi, V. K. (Oregon State Higher Education System, Sch. Engineering, Dept. Electrical & Computer Engineering, 200 Covell Hall, Corvallis, OR 97331).

The absorption characteristics of prolate spheroid models of man and animals exposed to electromagnetic radiation are being investigated. Specifically, the field distribution inside the prolate spheroid model consisting of homogeneous tissue characterized by known values of epsilon (omega), sigma (omega), and mu omicron at and near resonance will be calculated as a function of frequency of the incident radiation. The electromagnetic radiation will be a plane wave propagating in an arbitrary direction, polarized either in the plane of the wave vector and the major axis of the spheroid or normal to it. The power absorption pattern for these two cases will be evaluated as a function of frequency, eccentricity of the ellipsoid, and the direction of the wave vector. The total power absorbed and the relative absorption cross section also will be calculated. The analytic techniques to be employed include the spheroidal wave function expansion and the point matching technique using either the spheroidal or the spherical wave functions. The findings are essential for tissue absorbed power density estimates in terms of incident electromagnetic radiation to establish a sound electromagnetic safety standard. (9/76-9/77)

Supporting Agency:EPA

0225 INTERACTION OF AMPLITUDE (AM) NON-IONIZING EMR WITH BIOLOGICAL SYSTEMS (PART 5). Allis, J. W. (Developmental Biology Branch, Environmental Protection Agency, Experimental Biology Div., Durham, NC 27111).

Amplitude modulated or pulsed nonionizing electromagnetic radiation has been shown to affect animal behavior and the chemistry and physiology of certain isolated organ systems. Calcium ion has been attributed to interaction between the radiation and cellular membranes but has not yet been experimentally verified. This work will utilize membrane bound or calcium enzyme systems during irradiation by amplitude modulated radiation to determine if such effects can be inferred from changes in enzyme activity. Membrane bound or calcium dependent enzyme systems will be prepared and irradiated at 2,450 MHz amplitude modulated at various frequencies between 1 Hz and 5 kHz. Simultaneous spectrophotometric measurements of enzyme activity will be made and compared to controls. Measurements will be carried out using a crossed beam spectrophotometric

and microwave irradiation apparatus. The microsomal enzyme, nicotinamide adenine dinucleotide phosphate cytochrome C reductase is being investigated, and experiments with other membrane bound enzymes are planned. (10/76-9/77)

Supporting Agency:EPA

0226 MICROWAVE EXPOSURE SYSTEMS AND MICROWAVE DOSIMETRY. McRee, D. I. (Environmental Biophysics Lab., HEW, Natl. Inst. Environmental Health Science, Durham, NC 27709).

Exposure systems for bioeffects research and test techniques for measuring energy absorption are being developed. During the past year a waveguide system for exposing isolated neurons was fabricated and tested. Equipment for stimulating the nerves and measuring action potentials has been assembled. The 2,450 MHz absorber-lined horn system has been altered so that pregnant mice can be exposed from above. A wheatstone bridge circuit that can accommodate six small thermistor probes has been designed and built. The thermistor probes will measure colonic temperature in mice exposed to microwave radiation. (10/76-6/77)

Supporting Agency:HEW, PHS, NIH, Natl. Inst. Environmental Health Sciences

0227 DESIGN, CONSTRUCTION AND MODIFICATION OF MICROWAVE EXPOSURE SYSTEMS FOR BIOLOGICAL EXPERIMENTATION. Weil, C.; Allis, J. (Environmental Protection Agency, Health Effects Res. Lab., Durham, NC 27711).

An ultra high frequency exposure facility suitable for simultaneous irradiation of a sample with spectrofluorimetric observations will be designed and built. The exposure system will consist of a rectangular coaxial transmission line (Crawford cell) suitable for operation in the frequency range 0.5-2 GHz. The sample will be contained in a standard instrument cuvette, which will be located between the plates of the transmission line. Windows in the plates will allow passage of the ultraviolet light beams used for fluorimetric observations. The instrument will be modified using mirrors on an optical bench to provide for remote observations of the exposed sample. The transmission line exposure system was completed and tested in March, 1977. The optical modification to the spectrofluorimeter was received in January, 1977. (10/76-9/77)

Supporting Agency:EPA

0228 DESIGN, CONSTRUCTION AND MODIFICATION OF MICROWAVE EXPOSURE SYSTEMS FOR BIOLOGICAL EXPERIMENTATION. Weil, C. (Bioengineering Branch, Environmental Protection Agency, Health Effects Res. Lab., Durham, NC 27711).

A simple and economic exposure system will be

developed that is suitable for chronic low level exposures of rodents with a capability of directly measuring absorbed dose in each animal. Each exposure cell will consist of a length of 8-inch diameter circular waveguide, which contains a circularly polarized wave propagating at 915 MHz. Each cell will contain a single animal, and a power divider network will feed a total of 12 cells. A similar system using larger diameter cells is under consideration for exposing squirrel monkeys. Construction of the first unit commenced in March, 1976 and parts of the system have been completed. (10/76-9/77)

Supporting Agency:EPA

0229 EFFECTS OF 2450 MHZ MICROWAVE RADIATION ON BIOLOGICAL MATERIALS AT CELLULAR LEVEL. Hamrick, P. E.; McRee, D. I. (Environmental Physics Lab., HEW, Natl. Inst. Environmental Health Science, Durham, NC 27709).

The objectives of this project were to determine how 2,450 MHz microwave radiation interacts with biologic material at the cellular and macromolecular level, to observe any effects of this interaction, and to relate the amount of microwave energy absorbed to the effects. Biologic systems employed in the study were: bacteria and bacteriophage, solutions of DNA, 2-4 cell stage embryos from mice, rabbit erythrocytes, and rat lymphocytes. The temperature, humidity, and other growth conditions were carefully monitored to eliminate any effects not intrinsically caused by the microwave radiation. Very few non-thermal differences between exposed and control samples were detected. (10/76-9/77)

Supporting Agency:HEW, PHS, NIH, Natl. Inst. Environmental Health Sciences

0230 STUDIES OF MICROWAVE RADIATION AS A TOOL IN SOIL STERILIZATION AGAINST MAJOR DISEASES AND PESTS OF AGRICULTURAL CROPS. Wutoh, J. G. (Dept. Biology, Univ. Maryland, Princess Anne, MD 21853).

Soil samples from different soil types and locations were analyzed for soil microorganisms and arthropods before and after exposure to 2,450 MHz, 60 kW fully conveyORIZED microwave source. The effect of radiation on the soil organisms was assessed using the classical microbiologic method and the Dry-Funnel method for extraction of small arthropods. Current results indicate that: (1) all fungi were detected after treatment; (2) all bacteria except spore-forming types were killed; (3) all nitrogen fixing bacteria were inactivated and killed; (4) no nematodes survived; (5) all isolated arthropods (eggs, larvae, and adults) were killed; (6) there were no residual effects of the microwaves; (7) the effect of microwaves on the soil organisms was nonselective; (8) there was a correlation between moisture loss, and increase in soil temperature, and the associated mortality of the organisms;

and (9) seed germination and growth of soybeans was excellent in soil after 6 min of soil exposure but both germination and growth were retarded after 10 min of soil exposure. The effect was probably due to a change in soil structure and compactability caused by breakdown of organic matter. Future plans include a chemical analysis of soils from all 12 sites before and after a 20-min microwave exposure and growth studies of soybeans and peanuts in microwave sterilized soil to be performed in sterile gnotobiotic growth chambers. (10/77-9/78)

Supporting Agency:NASA

0231 EFFECTS OF MICROWAVES ON NEURAL RESPONSE. McRee, D. I.; Wachtel, H. (HEW, Natl. Inst. Environmental Health Science, Durham, NC 27709).

The effect of microwave radiation on neurologic response will be determined. Isolated neurons, such as, the abdominal ganglion of *Aplysia*, the sciatic nerves of frogs, and the saphenous nerves of cats will be exposed to continuous wave, pulsed, and modulated microwave radiation in the power density range of 1-10 mW/cm². The effects of the radiation on the strength-duration of a stimulus to produce an action potential, amplitude of the response, and conduction velocity will be investigated. Fatigue and recovery of the neurons under rapid, multiple stimulation will also be studied. A waveguide exposure system has been designed and built, and equipment for stimulation and recording of neural responses has been assembled. Baseline data on the sciatic nerve of frogs without microwave exposure have been accumulated and analyzed. (10/76-9/77)

Supporting Agency:HEW, PHS, NIH, Natl. Inst. Environmental Health Sciences

0232 BEHAVIORAL SYSTEMS DEVELOPMENT AND SUPPORT. Anderson, G. (Bioengineering Branch, Environmental Protection Agency, Health Effects Res. Lab., Durham, NC 27711).

A distributed minicomputer network will be provided within the laboratory for experiment monitoring and control. Specialized hardware interfaces will be developed for each remote minicomputer; a cathode ray tube (CRT)/terminal will provide operator interaction and access to programs and data within the host system. Data files generated at the remote minicomputer will be saved in the host disk files. Specially written software will provide a high-speed (4,800 baud) communication network between the various remote minicomputers and the host minicomputer. This approach provides the sharing of certain expensive peripherals, i.e., high speed line printer, graphics CRT-hardcopy, plotter, cartridge disks, etc., while keeping the distributed controllers' costs at a minimum. The system at present consists of a host and three remote minicomputers. One

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remote functions at a controller for determining locomotor activity of rodents in a system of residential mazes. A second is used for monitoring and control of a system of Skinner boxes for small animal behavioral testing. The third system is used for monitoring microwave exposure experiments and generating time interval histograms of dose. Re-programming will be provided as the various experiments are developed. Analysis will be accomplished either in real-time or later in the host as a batch-type operation. (10/76-9/77)

Supporting Agency:EPA

0233 ACCELERATION OF FRACTURE HEALING BY ELECTRICAL FIELDS. Brighton, C. T.; Frieden-berg, Z. B.; Black, J.; Hayes, W. C.; Fried, J. (Dept. Orthopedic Surgery, Univ. Pennsylvania, Sch. Medicine, 36th & Hamilton Walk, Philadelphia, PA 19104).

The optimum electrical parameters for accelerating fracture healing will be determined, and the mechanism of electrically-stimulated fracture healing at the cell level will be investigated. The immediate research goals are to: (1) determine the optimum current density and the optimum magnetically-induced current for osteogenesis, (2) compare ultrastructural changes in medullary canal cells in vicinity of active cathode with those in control canal, (3) map the surface charge of cell membranes of chondrocytes growing in an electrical field and compare it to that of control chondrocytes, and (4) determine tissue pO_2 , CO_2 , and pH changes occurring in medullary canal of the dog tibia subjected to a direct current of 20 μ amps. (9/77-8/78)

Supporting Agency:HEW, PHS, NIH, NIAHDD.

0234 DEVELOPMENT OF ELECTROMAGNETIC RHEOANGIOGRAPHY. Kolin, A.; Macalpin, R. N.; Steckel, R. J.; Snow, H. D. (Dept. Ophthalmology, Univ. California, Sch. Medicine, 405 Hilgard Ave., Los Angeles, CA 90024).

This project will complete the development of a newly devised electromagnetic method for simultaneous measurement of average and phasic volume rate of blood flow, blood velocity, and vascular diameters in human subjects. The method utilizes a magnet external to the patient's body so that its magnetic field transverses the blood vessels including an electromotive force in the blood stream, which constitutes the flow signal. The induced flow signal is picked up by an ultraminiature intravascular probe that is inserted into the vessels much as a guide wire via an angiographic catheter (the probe is a loop of insulated spring wire 0.1 mm in diameter). The loop probe can be inserted into small branches of the aorta via angiographic catheter of standard size (#7 French) and will easily pass through much smaller catheters (down to #4 French). The same transducer can be utilized to detect minute variations in phasic and average artery diameter. It is proposed to perfect such

transducers to permit measurements in arteries and veins down to 1 mm in diameter and to develop appropriate methods of "delivery," i.e., of conveying the sensing element to the appropriate blood vessel and assuring optimal position and orientation of the sensor relative to the external magnetic field. The proposed research will explore all the important blood vessels supplying the vital organs (such as, renal, mesenteric, internal carotid, and coronary arteries) and develop the simplest possible techniques of recording regional blood flows. The investigation will proceed from anesthetized animals to conscious patients. The work will involve improvement of the design of the flow and diameter sensors as well as of the electronic channels for amplification of the electrical flow signals for current supply to the magnet. This method has been applied to cancer research to explore the possibility of achieving enhanced radio-sensitivity of tumors as compared with the ambient normal tissues by intra-arterial administration of a vasoconstrictor. (9/77-11/77)

Supporting Agency:HEW, PHS, NIH, Natl. Heart Lung & Blood Inst.

0235 EFFECTS OF MULTIPLE RF RADIATION EXPOSURES. Krupp, J. H. (U.S. Air Force, Sch. Aerospace Medicine, Brooks Air Force Base, San Antonio, TX 78235).

An attempt will be made to define a radio frequency (RF) radiation effect on humoral antibody production. Such an effect would impair the ability of exposed personnel to withstand infection and develop immunity in response to challenges in the environment. Hybrid inbred mice will be exposed for prolonged periods (up to 6 wk) to RF radiation at frequencies and power levels scaled to represent equivalent human exposure. Following exposure, an antigenic challenge will be made, and the response assayed by measuring the presence of splenic plaque-forming cells. Where RF effects can be detected, further study will try to define threshold levels, thermal versus nonthermal characteristics, and relative efficiency for production of effects from continuous wave or pulsed application over extended periods. (10/76-9/77)

Supporting Agency:U.S. Dep. Def., Air Force

0236 BEHAVIORAL AND BIOLOGICAL EFFECTS OF RESONANT ELECTROMAGNETIC POWER ABSORPTION IN RATS. Gandhi, O. P.; Johnson, C. C. (Utah Higher Education System, Sch. Engineering, Dept. Electrical Engineering, 1400 E. 2nd St., Salt Lake City, UT 84112).

The behavioral and biologic effects of resonant electromagnetic power absorption in rats will be determined in order to develop realistic exposure criteria for military personnel. The parallel-plate wave guide will be used to generate plane waves for exposure of the experimental animals.

Exposures will be made with animals oriented along the E, H, and K axes. Frequency will be established based on the frequency of peak absorption; frequencies of 0.5, 0.75, 1.0, 1.25, and 1.5 times this resonant frequency will be used. (10/77-9/78)

Supporting Agency:U.S. Dep. Def., Army

0237 DESIGN, CONSTRUCTION AND MODIFICATION OF MICROWAVE EXPOSURE SYSTEMS FOR BIOLOGICAL EXPERIMENTATION. Ali, J. S. (Bioengineering Branch, Environmental Protection Agency, Health Effects Res. Lab., Durham, NC 27711).

An environmental control system will be installed in an X-band microwave exposure facility to regulate the air temperature and humidity in both an animal exposure chamber and a sham irradiation chamber. The exposure chamber and sham chamber will be constructed of foamed polystyrene for microwave transparency and good thermal insulation. The temperature will be controllable from -10.0 to +40.0 C with a stability of ± 1.0 C and the relative humidity will be controllable from 20% to 90%. The two foam chambers will be connected to the air conditioning equipment using insulated ducts. The air conditioning equipment will have remote control inputs and recorder outputs, which will facilitate computer control. (10/76-9/77)

Supporting Agency:EPA

0238 TDR MEASUREMENT OF DIELECTRIC PARAMETERS OF BIOLOGICAL MATERIALS. Kinn, J. B. (Bioengineering Branch, EPA, Health Effects Res. Lab., Durham, NC 27711).

The broadband dielectric behavior of biologic materials including tissue and micro-organisms will be determined, and the frequency dependence of the complex permittivity will be examined. The portion most influenced by radio frequency (RF) and microwave radiation will be identified. Time domain reflectometry (TDR) will be employed to study dielectric behavior. The incident and reflected pulse transmitted to the sample in a coaxial waveguide will be recorded with a minicomputer. The data will then be processed using a Fast Fourier Transform in a large computer yielding complex permittivity as a function of frequency. Part of the TDR data has been collected and is being processed. The remaining data will be collected and processed with subsequent examination of the RF dispersion portion of the complex permittivity. (10/76-9/77)

Supporting Agency:EPA

0239 LABORATORY INSTRUMENTATION SUPPORT. Ali, J. S. (Bioengineering Branch, Environmental Protection Agency, Health Effects Res. Lab., Durham, NC 27711).

This project is designed to assure the operation of critical instrumentation used for chronic long-term microwave studies. Calibration of microwave instrumentation is performed routinely to guarantee accurate dosimetry. Special electronic instrumentation is designed to facilitate microwave exposures, and measurement of critical parameters and operating manuals are prepared for microwave exposure facilities. (10/76-9/77)

Supporting Agency:EPA

0240 BIOLOGICAL EFFECTS AND HAZARDS OF MICROWAVE RADIATION. Hunt, E. L.; Larsen, L. E. (U.S. Army, Walter Reed Army Inst. Res., Washington, DC).

An attempt will be made to establish meaningful criteria for delimiting human occupancy in an electromagnetic (EM) environment to achieve maximum operational effectiveness of military personnel and eliminate health risk. The interaction of radio frequency and microwave radiation (10 MHz-100 GHz) with biologic systems will be delineated. In addition, established EM dosimetry techniques will be evaluated and developed to measure and control incident and absorbed energy. Each major organ system and biologic process will be investigated where EM effects might occur at reasonably low power intensities. The military significance of the effects will be determined, and measures necessary to obviate them will be evaluated. A multidisciplinary approach will be used including methods of experimental psychology, biophysics, physiology, and engineering. Exposure parameters will be chosen for relevance to Army radiating equipment operational requirements. (10/77-9/78)

Supporting Agency:U.S. Dep. Def., Army

0241 INTERACTIONS OF AMPLITUDE MODULATED (AM) NON-IONIZING EMR WITH BIOLOGICAL SYSTEMS. Whitcomb, E. R. (Neurobiology Branch, Environmental Protection Agency, Health Effects Res. Lab., Durham, NC 27711).

To determine if amplitude-modulated (AM) radiant energy can modify the contractility of smooth muscle, the interval histogram patterns of smooth muscle spontaneous contraction prior to and during exposure will be compared. Preliminary radiant energy studies indicated no effects by amplitude modulated radiant energy at .2, .5, 16, 600, and 2,000 Hz. (10/76-9/77)

Supporting Agency:EPA

0242 EFFECTS OF RADIO & RADIO FREQUENCIES ON BIOSYSTEMS--MICROWAVE EXPOSURE SYSTEMS FOR BIOLOGICAL EXPERIMENTS (ABBREV). Allis, J. W.; Weil, C. M. (Developmental Biology Branch, Environmental Protection Agency, Experimental Biology Div., Durham, NC 27111).

CURRENT RESEARCH

Fluorometry can provide measurements of properties of biologic membranes and biopolymers that are not attainable using other optical techniques. If such measurements can be made while a sample is irradiated with nonionizing electromagnetic radiation, changes in these biologic systems can be detected. A fluorometer will be modified to accept an exposure facility so that a sample may be irradiated over a wide range of frequencies simultaneous with fluorometric measurements. Membrane and biopolymer systems will be investigated for a variety of properties detectable by this technique. (10/76-9/77)

Supporting Agency:EPA

0243 MICROWAVE EFFECTS. Tredici, T. J. (U.S. Air Force, Sch. Aerospace Medicine, Brooks Air Force Base, San Antonio, TX 78235).

A detailed initial ophthalmologic evaluation and follow-up will be provided for Air Force personnel who have suffered a microwave overexposure, i.e., exposure greater than twice the permissible exposure limit. Attention will be focused on the presence or absence of lenticular lesions and the possible causal relation of microwave exposure. Patients will be evaluated in the ophthalmology branch, clinical sciences division, School of Aerospace Medicine at Brooks Air Force Base following standard patient evaluation protocols. Follow-up will be established on an individual basis and reports will be made to the referring physician and medical facility. When sufficient data have been accumulated, the material will be published. (10/76-9/77)

Supporting Agency:U.S. Dep. Def., Air Force.

0244 INTERACTIONS OF AMPLITUDE-MODULATED (AM) NON-IONIZING ELECTROMAGNETIC RADIATION WITH BIOLOGICAL SYSTEMS. Blackman, C. F. (Environmental Protection Agency, Experimental Biology Div., Durham, NC 27111).

Bacterial and mammalian cell systems will be exposed to a series of amplitude-modulated (AM) frequencies to determine the effect on various physiologic activities. A bench top radiation exposure system has been constructed that can deliver AM radiation to in vitro samples. Preliminary tests are underway with brain tissue and bacterial and mammalian cells. (10/76-9/77)

Supporting Agency:EPA

0245 CONSTRUCT A CRAWFORD CELL FOR EXPOSURE OF ANIMALS TO FM RADIATION. Weil, C. (Bioengineering Branch, Environmental Protection Agency, Health Effects Res. Lab., Durham, NC 27711).

An exposure facility suitable for irradiating rodents at the same frequency used in frequency

modulation (FM) radio broadcasting was designed and built. Recent monitoring work has shown that FM broadcasting presents a significant potential for human exposure to radio frequency microwave radiation. A rectangular coaxial transmission line facility (Crawford cell) provides a simple and economic method of exposing test animals to 3-m radiation. Eighteen rats will be simultaneously exposed to an equivalent plane wave field of approximately 10 mW/cm². Although construction of the exposure system has been completed, experiments have not yet commenced due to RF leakage problems as well as high ambient noise levels in the vicinity of both chambers. (10/76-9/77)

Supporting Agency:EPA

0246 INFRARED ANALYSIS OF DOSE DISTRIBUTION IN ANIMALS AND PHANTOM MODELS EXPOSED TO MICROWAVE RADIATION. Kinn, J. B.; Weil, C. M. (Bioengineering Branch, Environmental Protection Agency, Health Effects Res. Lab., Durham, NC 27711).

The distribution of absorbed energy in a complex biologic system and in equivalent phantoms will be determined experimentally using infrared thermographic analysis of sectioned animals and equivalent phantoms. An infrared thermographic scanner has been purchased and a minicomputer/software system is being designed to collect scans. The basic picture processing software package is operational and additional software is being designed and written. (10/76-9/77)

Supporting Agency:EPA

0247 OCCUPATIONAL EXPOSURE OF U.S. NAVY VETERANS OF THE KOREAN WAR TO MICROWAVE RADIATION (RADAR). Robinette, C. D.; Silverman, C. C.; Beebe, G. W. (Nat'l. Res. Council, 2101 Constitution Ave. N.W., Washington, D.C. 20037).

Approximately 20,000 men who served as electronics repairmen in the U.S. Navy during the Korean War are being traced to determine whether they have elevated mortality from cancer or from other causes. Controls are about 20,000 men who served as radio and radar operators in the Navy during the Korean War. The period of follow-up extends from January 1956 through December 1974. (10/76-9/77)

Supporting Agency: not reported.

0248 TWIN-CELL CALORIMETRY SUPPORT OF IN VIVO ANIMAL STUDIES FOR WHOLE BODY EMR ABSORPTION. Kinn, J. B. (Bioengineering Branch, U.S. Environmental Protection Agency, Health Effects Res. Lab., Durham, NC 27711).

The total energy absorbed in a complex biologic system exposed to electromagnetic fields will be determined experimentally. A twin-well calorimeter

for in vivo animal studies of total body electromagnetic radiation absorption will be employed. Four calorimeters have been constructed and used in studies involving rats, hamsters, and mice. Four additional units are being made and will be used in the above studies and in determination involving equivalent microwave phantoms. (10/76-9/77)

Supporting Agency:EPA

0249 BIOPSYCHOLOGICAL STUDIES OF MICROWAVE IRRADIATION. Justesen, D. R.; Sheridan, C. L.; Garrison, R. G.; Levinson, D. M. (Dept. Psychiatry, Univ. Kansas, Sch. Medicine, 39th & Rainbow Blvd., Kansas City, KS 66101).

Dose-determinate exposures of gravid mice and rats to 2,450-MHz and 915-MHz microwave energy will be performed in a multi-mode cavity in studies of lethal-dosing, teratology, longevity, and maze-learning. Corollary studies will: (1) evaluate the role of endogenous (psychogenic) heating in mammals, as induced by handling and restraint in lethality of dosing, (2) examine growth and ultra-structure of a thermophilic organism that exhibits retarded growth and hyperplasia of the plasma membrane under microwave radiation, (3) record the ethogram of an avian species previously incubated in a microwave field, (4) determine the utility of evoked thermal responses as indicators of perception of microwave energy, and (5) investigate the use of hypothermal agents in mammals to find a biodosimeter of absorbed electromagnetic energy. The effects of continuous wave and pulsed radiations of the same averaged density will be compared. (9/77-8/78)

Supporting Agency:HEW, PHS, FDA

0250 MICROWAVE DOSIMETRY IN BIOLOGICAL SYSTEMS. Weil, C. (Bioengineering Branch, Environmental Protection Agency, Health Effects Res. Lab., Durham, NC 27711).

A broadband (0.1-3 GHz) isotropic field probe, suitable for measuring perturbed or scattered fields in the region where animal subjects are to be irradiated (in both transmission line resonant cavity and anechoic chamber exposure facilities) will be obtained. (10/76-9/77)

Supporting Agency:EPA

0251 MICROWAVE DOSIMETRY IN BIOLOGICAL SYSTEMS. Ward, G. H.; Kinn, J. (Bioengineering Branch, Environmental Protection Agency, Health Effects Res. Lab., Durham, NC 27711).

Interface hardware and control software will be developed for an infrared (IR) microscanner that will be connected to a distributed minicomputer

network. The computer system will be used for data acquisition and control. The video signal from the IR microscanner will be converted to a digital signal by A/D conversion and stored in a minicomputer system for analysis. Software will be written to control the interface timing and data acquisition. Hardware interface concepts are being designed and computer hardware and A/D converter are being ordered. (10/76-9/77)

Supporting Agency:EPA

0252 EFFECTS OF LOW INTENSITY MICROWAVE RADIATION ON MAMMALIAN SERUM PROTEINS.

Cleary, S. F.; Berry, E. R. (Dept. Biophysics, Virginia Commonwealth Univ., Sch. Medicine, 1200 E. Broad St., Richmond, VA 23298).

See Current Research 0201 for description of this research. (10/77-9/78)

Supporting Agency:U.S. Dep. Def., Army

0253 2450 MHZ MICROWAVE ABSORPTION IN LARGE AND SMALL ANIMALS AND ITS BIOBEHAVIORAL EFFECTS ON BIRDS AND REPTILES. Ghandi, O. M. (Utah Higher Education System, Graduate Sch., 310 Park Building, Salt Lake City, UT 84112).

No descriptive information is available. (3/77-9/77)

Supporting Agency:NASA

0254 BIOLOGICAL AND ECOLOGICAL EFFECTS OF ENERGY TRANSMISSION BY MICROWAVES (EFFECTS OF 2,450 MICROWAVE ILLUMINATION ON PLANT GROWTH). Ward, C. H. (Dept. Biology, Rice Univ., 6100 Main St., Houston, TX 77001).

No descriptive information is available. (3/77-9/77)

Supporting Agency:NASA

0255 CLINICAL TRIALS ON PARTIALLY PARALYZED CHILDREN TO DETERMINE EFFICACY OF IMPLANTABLE RADIO FREQUENCY NERVE STIMULATION. Anonymous. (Georgetown Univ., Sch. Medicine, 3900 Reservoir Rd. N.W., Washington, DC 20007).

No description information is available. (8/76-7/77)

Supporting Agency:Dr. Scholl Foundation, Chicago, IL

CURRENT RESEARCH

*Biological Effects of Nonionizing Electromagnetic
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0256 STUDY DEVELOPED DISUSE OSTEOPOROSIS IN
 ANIMAL TROPOROSIS. Bassett, C. A. (Colum-
bia Univ., Sch. Medicine, 630 W. 168th St., New
York, NY 10032).

No descriptive information is available. (1/77-12/77)

Supporting Agency:NASA

0257 STUDIES OF MICROWAVE RADIATION AS A TOOL
 IN SOIL STERILIZATION AGAINST MAJOR DISEASES
AND PESTS OF AGRICULTURAL CROPS. Wutoh, J. G. (Univ.
Maryland, Princess Anne, MD 21853).

No descriptive information is available. (11/76-1/78)

Supporting Agency:NASA

CURRENT LITERATURE

- 5224 AN EXPERIMENTAL PERMEABILIZATION OF THE BLOOD-BRAIN BARRIER BY ELECTRIC FIELD APPLICATION. (Eng.) Dereymaeker, A. (290, Waversebaan, B-3030 Heverlee, Belgium); Gonsette, R. *Eur Neurol* 15(6): 333-339; 1977. (20 refs)

The effect of transcerebral electrolysis on the permeability of the blood-brain barrier in rabbits was investigated. A direct current ranging from 1-30 mA was applied to electrodes attached to the animal's bony skull over periods ranging from 1-20 min. The potential difference across the electrodes ranged from 10-60 V. When the transcerebral electric field was limited to 5 mA or less and when broad (1 cm²) electrodes were used, no morphologic lesions were found in the brain parenchyma and the animal's behavior and electroencephalogram remained normal. At nontraumatizing electric field levels, the blood-brain barrier was made permeable to trypan blue dye, radioisotopic tracers, penicillin, and several epileptogenic drugs. The permeability lasted for several days. At transcerebral electric fields of greater than 5 mA, several adverse effects were observed including four-legged paresia, hypersensitivity to noise and light, loss of appetite followed by exhaustion and death, epileptoid electroencephalographic spikes, and morphologic brain lesions. When pin electrodes, which were driven into the skull, were used in place of broad electrodes, hemorrhagic lesions were observed. It is concluded that this method may be applied to clinical therapy. In this way pharmaceutical or physiologic substances, which normally do not pass the blood-brain barrier, can be brought to the brain parenchyma.

- 5225 THE POTENTIAL OF SATELLITE SOLAR POWER. (Eng.) Glaser, P. E. (Arthur D. Little, Inc., Acorn Park, Cambridge, MA 02140). *Proc IEEE* 65(8): 1162-1176; 1977. (33 refs)

The design of a satellite solar power system (SSPS) is outlined, with reference to potential environmental and biological impacts of a microwave power transmission system designed to transmit the electrical power generated by the SSPS to a receiving antenna on earth. The SSPS will incorporate several fail-safe features to assure control of microwave beam pointing and instantaneous shutoff of power to the microwave generators. Failure of the microwave beam-pointing system will not result in exceeding the international standards for microwave exposure. Possible effects, if any, on birds flying through the microwave beam will have to be established. Preliminary evidence indicates that birds can be affected at levels of microwave exposure greater than 25 mW/cm² of radiation in the X-band. The effects of microwave exposure on aircraft flying through the beam must also be considered. Significant human exposure is unlikely because of the shielding effects of aircraft metal fuselages and the short flight time through the beam. The extent of possible interference with aircraft communication and radar equipment will have to be established.

In terms of environmental considerations, forward scattering by rain and hail will increase the field intensity outside the main microwave beam. For example, a 5-GW SSPS operating at a frequency of 3 GHz would scatter 3 mW nearly isotropically, if the storm cell height is 1 km. At a range of 10 km, the scattered microwave beam power density would be about 2×10^{-4} mW/cm². Therefore, scattering by rain or hail is not expected to significantly increase sidelobe levels or broaden the main microwave beam. Microwave power densities above 20 mW/cm² could result in major changes in ionospheric properties, and the effects of changes in ionospheric electron density caused by microwave power densities of 20 mW/cm² at the SSPS operating frequency will have to be assessed in terms of possible effects on other uses of the ionosphere.

- 5226 EPIPHYSEAL CARTILAGE cAMP CHANGES PRODUCED BY ELECTRICAL AND MECHANICAL PERTURBATIONS. (Eng.) Norton, L. A. (Dept. Orthodontics, Univ. Connecticut Health Center, Farmington, CT 06032); Rodan, G. A.; Bourret, L. A. *Clin Orthop* (124): 59-68; 1977. (60 refs)

Epiphyseal cartilage from chick embryo was subjected in vitro for 1-15 min to static compressive forces or oscillating electric fields. The same stimuli were applied to suspensions of cells isolated from the epiphyses. At the end of the perturbation, 3', 5'-cyclic adenosine monophosphate (cyclic AMP) was measured in the tissue or cell extracts by radioimmunoassay. A physiologic (60 g/cm²) static pressure reduced the cyclic AMP content in tissue and in separated cells. An oscillating electric field above 900 V/1.5 cm (5 Hz) enhanced the cyclic AMP accumulation in intact tissue, and this effect was produced only when the long axis of the bones was oriented parallel to the electric field. In isolated cells, an electric field above 750 V/1.5 cm (5 Hz) caused a decrease in cyclic AMP content. Charged matrix macromolecules and orientation of the cells within the cell matrix may have a modulating effect on the initiation of this response. It is postulated that the change in cyclic AMP is the early cellular signal in the response to an electrical or mechanical perturbation that leads to bone remodeling.

- 5227 THE EFFECT OF MEAT TREATED WITH SUPERHIGH FREQUENCY ENERGY AND INFRARED RAYS ON THE SECRETORY FUNCTION OF THE STOMACH. (Rus.) Kulakova, S. N. (Inst. Nutrition, USSR Acad. Medical Sciences, Moscow, USSR); Laktaeva, T. V. *Vopr Pitan* (4): 24-29; 1977. (10 refs)

The effects of meat prepared in commercial microwave oven (frequency 433 MHz), in infrared (IR) oven, and by a combination of the two methods on gastric secretion were studied in Pavlov's and Heidenhain's pouches of dogs fed 100 g of meat.

Meat prepared in the microwave oven caused significant increase in gastric juice secretion compared with conventionally cooked meat in dogs with Pavlov's pouch. Additional infrared treatment of the meat caused a slight increase in the secretion over that caused by microwave irradiation. Gastric juice secretion was enhanced by microwave treatment mainly during (Phase I) the first 2 hr (29.86 ± 1.38 vs. 25.09 ± 1.16) after feeding ($P < 0.02$). Secretion showed a tendency toward increased values beyond the first 2 hr (12.82 ± 1.37 vs. 9.71 ± 0.98) in the control dogs fed 100 g of conventionally-cooked meat ($P < 0.1$). The total acidity and the free hydrochloric acid content of the gastric juice secreted in response to microwave-prepared meat did not undergo any substantial changes. The secretion of total proteinases with the gastric juice per unit time (1 hr) was higher with meat prepared in microwave oven than in the case of conventionally-cooked meat. Meat prepared in microwave oven increased the gastric secretion in dogs with Pavlov's and Heidenhain's pouches. The findings suggest that treatment of meat with microwave and/or IR radiation caused the formation of substances, which stimulate the first phase of the gastric secretion.

- 5228 IMMUNOLOGICAL REACTIVITY OF THE BODY UNDER THE EFFECT OF SUPER-HIGH FREQUENCY ELECTROMAGNETIC FIELDS UNDER THE CONDITIONS OF DIFFERENT ULTRAVIOLET RADIATIONS. (Rus.) Shutenko, O. I.; (Kiev Medical Inst., Kiev, USSR); Vinogradova, G.; Uzhva, N. F. *Gig Sanit* (8): 48-50; 1977. (1 ref)

The effect of super-high frequency electromagnetic field (100 or 1,000 $\mu\text{W}/\text{cm}^2$ 3 hr/day) on the immunologic reactivity of male albino rats was studied under conditions of ultraviolet (UV) radiation of various doses. In rats with UV deficit, exposure to 1,000 $\mu\text{W}/\text{cm}^2$ field caused significant increase in the rate of basophil degranulation (33% vs. 1.65% in rats kept under the conditions of UV deficit), in the percentage of plaque-forming cells (4.74% vs. 0.28%), and in the phagocytic index (87.2% vs. 64.2%). The positive Ierne-Klemparskaya test, used to determine number of immunocompetent cells in the peripheral blood, is indicative of autoallergic reaction to high-frequency electromagnetic field. Irradiation with prophylactic UV dose averted the autosensitization processes and protected, to a certain degree, the immune system from the damaging action of the electromagnetic field. Irradiation with a UV dose of 1,600 mc/cm^2 intensified the changes induced by the electromagnetic field.

- 5229 EFFECT OF ELECTROMAGNETIC ENERGY OF INDUSTRIAL FREQUENCY ON THE HUMAN AND ANIMAL NERVOUS SYSTEM. (Rus.) Popovich, V. M. (Lab. Electrical and Electromagnetic Environmental Factors, Kiev Scientific Res. Inst. of General and Communal Hygiene, Kiev, USSR); Kozlarsin, I. P. *Vrach Delo* (6): 128-131; 1977. (0 refs)

The physiologic and biochemical effects of electro-

magnetic fields of 50 Hz frequency, generated by high-voltage electric transmission lines and transformers, were studied in albino rats and in human volunteers. The animals were exposed to fields with intensities of 1-15 kV/m, 2 hr daily for 4 mo. Significant ($P < 0.05$) increase was observed in the cumulative threshold index in animals exposed to 7 and 15 kV/m fields (17.3 and 19.1 vs. 11.7 in the control). The latency period of unconditioned reflexes was 67 msec and 69.6 msec in the above groups vs. 51 msec in the unexposed control rats ($P < 0.05$). The chronaxy ratio of the antagonistic muscles of the leg was 0.5 and 0.4 in the groups exposed to 7 and 15 kV/m vs. 1.9 in the control ($P < 0.05$). The blood cholinesterase activity increased significantly in the group exposed to 15 kV/m (150.2 $\mu\text{g}/\text{min}$ vs. 130.8 $\mu\text{g}/\text{min}$ in the control; $P < 0.05$). Men and women (aged 23-47 yr) who were exposed to 5 kV/m fields, 2 hr daily for 30 days, or to 12 kV/m fields for 3 x 30 min at 1 hr intervals for 6 days, showed no significant changes in the above parameters. Other human volunteers, exposed to a 15 kV/m field 3 x 30 min daily for 6 days presented with transient headache, fatigue, irritability, and showed significantly increased bioelectric potentials evoked by rhythmic photostimulation (artificial flashing light) at 12 Hz frequency. The findings indicate that the permissible level of electromagnetic field is 5 kV/m for up to 2-hr exposure daily and 12 kV/m for 3 x 30 min exposures at 1-hr intervals.

- 5230 REDUCTION OF THE FUNCTIONAL POSSIBILITIES OF THE HEART UNDER THE EFFECT OF ELECTROMAGNETIC FIELD OF INDUSTRIAL FREQUENCY. (Rus.) Prokhvatilo, E. V. (Kiev Scientific Res. Inst. of General and Communal Hygiene, Kiev, USSR). *Vrach Delo* (7): 141-143; 1977. (6 refs)

The electroencephalographic effects of electromagnetic fields of industrial frequency (50 Hz, intensity 100, 300 or 1,000 V/m, exposure time 60 days) on the cardiac function were studied in rabbits. Exposure to 100 and 300 V/m fields had no effect on the cardiac function, while 1,000 V/m caused considerable changes: reduction of the cardiac rate from 291/min before to 266/min after 30-60 days of exposure, reduction of the force of the atrial contraction by 50% ($P < 0.001$), reduction of the force of the ventricular contraction (reduction of the R wave potential from 0.38 to 0.20 mV ($P < 0.001$), reduction of the T wave potential from 0.10 mV to 0.8 mV ($P < 0.01$), and shift of the ST segment to below the isoelectric line. The orthostatic function test with the rabbits in upright position showed 34-46% increase of the cardiac rate (22-32% in the control), 30% reduction of the P wave potential (14-23% in the control), 39-72% reduction of the R wave potential (14-29% in the control), and 32-49% reduction of the T wave potential (25-33% in the control). The findings indicate the deleterious effect of electromagnetic fields of industrial frequency on the contraction, repolarization, and function of the heart.

5231 ALTERNATING MAGNETIC FIELD EFFECT UPON
HEALING OF ULCERS OF THE LOWER EXTREMITIES.

(*Rus.*) Tiuriaeva, A. A. (Railroad Hosp. No. 2, Perm-II, USSR); Ponizovskii, V. M.; Akimov, G. L. *Vestn Khir* 119(8): 84-85; 1977. (2 refs)

Sixty-seven patients with ulcerative lesions of the lower extremities were treated with alternating magnetic field (AMF: 50 Hz, 400 Oe) in daily sessions. Of the 67 patients, 43 were over 50 yr of age. Thirty-seven patients had had ulcers for less than 1 yr, 12 for 1-3 yr, 18 for over 3 yr. Neurotrophic ulcer was diagnosed in 4 patients, trophic ulcer in 15, varicose ulcer in 48. Suppuration disappeared usually after 3-5 sessions. Granulation and epithelialization of the ulcers began after 5-9 sessions. The cicatricial tissue formed was elastic and not fused with the underlying tissues. Complete ulcer healing was achieved in 57/67 patients; AMF was most successful with varicose ulcers. Fifty-one patients were followed for 1-7 yr; permanent healing was achieved in 42/51, while 9 developed recurrences. A similar control group of 30 patients received conventional therapy: cicatrization was observed in 4 and reduction of the size of the ulcer in 15. There was no response to therapy in 11 patients. The findings indicate the high efficiency of AMF in the treatment of ulcers of the lower limbs.

5232 METHODS OF DOSIMETRY AND MEASURING IN
MICROWAVE FIELDS. (*Rum.*) Vasilescu, V.

(Laboratorul de biofizica, Institutul de medicina si farmacie, Bucharest, Romania); Zaci, C. *Rev Ig [Pneumoftiziol]* 26(2): 137-144; 1977. (25 refs)

Basic principles of modeling and calculating methods to determine microwave doses in biologic matter (tissues) are reviewed. The total dose absorbed by the experimental animal determines the biologic effect of microwaves. The total dose rate absorbed as a function of time varies in animals freely moving in a cage, while the dose rate is nearly constant in immobilized animals.

5233 THE DEVELOPMENT OF METHYLCHOLANTHRENE-
INDUCED TUMORS IN MICE UNDER THE ENVIRON-
MENTAL INFLUENCE OF VARIOUS ELECTROBIOTIC CLIMATOLOGIC
CONDITIONS. (*Ger.*) Moese, J. R. (Hygiene-Institut, Universitat Graz, A-8010 Graz, Universitatsplatz 4, Austria); Fischer, G. *Zentralbl Bakteriol [Orig B]* 164(5/6): 447-454; 1977. (15 refs)

The effects of electrostatic field (field strength 200 V/m, residual wave component 0.1%), of a Faraday cage with shielding of atmospheric electrical disturbances at 99% efficiency, and a climatized laboratory on the tumor induction rate were studied in 8-wk-old female NMRI-Han mice that received 0.1 mg of methylcholanthrene subcutaneously after a 6-wk adaptation period. The animals were examined for tumors at 2-wk intervals for 210 days. At the end of the experiment, the tumor induction rate was higher in the mice kept under conventional

laboratory conditions (over 60%) and significantly lower (around 40%) in mice kept in Faraday cages or in electrostatic field with 0.1% residual wave component. No difference was apparent between the latter two conditions. The findings indicate that changes in the electroclimatic environment may induce unspecified stress reactions, resulting in reduced immunologic dynamics.

5234 LIQUID CRYSTAL ELECTROMAGNETIC RADIATION
MONITOR. (*Eng.*) Fanslow, G. E. (Dept.

Electrical Engineering, Engineering Res. Inst., Iowa State Univ., Ames, IA 50011). *J Microwave Power* 12(1): 87-91; 1977. (16 refs)

A liquid crystal calorimeter designed for monitoring nonionizing electromagnetic radiation is described. Liquid crystals having color play centered at different temperatures were arranged on metal-coated and nonmetal-coated dielectric substrates. While both substrates responded to changes in ambient temperature conditions, the metallized substrate also responded to temperature changes due to absorbed radiation. The difference between the temperature indications of the two substrates was a measure of the radiation. Using an experimental liquid crystal calorimeter that measured radiation of 1-15 mW/cm² at a frequency of 2.45 GHz, measurements were made over an ambient temperature range of 18.89-25 C. Over this range, the approximate rise in temperature of the metallized disk was 0.59, 2.22, and 4.44 C above ambient for radiation levels of 1, 5, and 10 mW/cm², respectively. In its simplest form, the calorimeter can be used as a simple indicator tuned to one frequency and used for regular safety checks. An advantage of liquid crystal calorimetry for monitoring nonionizing radiation is that liquid crystals are used for both the measuring and indicating functions, excluding the need for electronic metering.

5235 EFFECT OF MICROWAVE RADIATION ON CELLS
TREATED WITH MEMBRANE-INJURING SUBSTANCES.

(*Eng.*) Szmigielski, S. (Center for Radiobiology and Radioprotection, Szaserow 128, 00-909, Warsaw, Poland); Kobus, M.; Janiak, M.; Rytko, J. *Exp Pathol (Jena)* 13(6): 296-301; 1977. (26 refs)

The effect of microwave radiation on cells treated with membrane-injuring substances was investigated. A continuous line of human embryonic cells (WISH) grown in vitro were pretreated with subcytotoxic concentrations of digitonin, cortisol, and purified bacterial toxins (staphylococcal beta-hemolysin or *Clostridium perfringens* alpha-toxin) and were irradiated with 3 GHz microwaves at field power densities of 5 or 40 mW/cm². At 40 mW/cm², an increase of about 2-3 C in the temperature of the culture medium was noted, while at 5 mW/cm² no detectable increase in temperature was observed. Irradiation with microwaves resulted in a lowering of the thymidine and glycine incorporation into cells along with changes in the intracellular amount of cyclic adenosine monophosphate (decrease in cells

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exposed to 5 mW/cm² and increase in cells exposed to 40 mW/cm²). Under both field power densities, viability of the cultures was normal. Pretreatment of cells with digitonin or purified bacterial toxins followed by irradiation with microwaves resulted in an enhancement of the cytotoxic effect of the membrane-injuring substances, with a lowering of cell viability, especially after exposure to power densities of 40 mW/cm². Cortisol did not influence the reaction of cells to microwave radiation. It is concluded that substances injuring cell membranes sensitize cell cultures to microwave radiation and may enhance the specific (nonthermal) effect of microwaves.

- 5236 BIOELECTRICITY AND REGENERATION: LARGE CURRENTS LEAVE THE STUMPS OF REGENERATING NEWT LIMBS. (Eng.) Borgens, R. B. (Dept. Biological Sciences, Purdue Univ., Lafayette, IN 47907); Vanable, J. W.; Jaffe, L. F. *Proc Natl Acad Sci* 74(10): 4528-4532; 1977. (27 refs)

Electrical currents near regenerating newt limbs were measured with a vibrating probe operating at a resonant frequency of 310-320 Hz, a peak-to-peak amplitude of 70 μ m, and a time constant of 1 sec. Steady currents with local surface densities of 10-100 μ A/cm² or more left the end of the stump during the first 5-10 days after amputation, and currents with low densities of 1-3 μ A/cm² entered the intact skin around the stump. Large outward currents showed a strong tendency to peak over clear, newly-formed epithelium and rarely appeared over fully-pigmented mature skin. Current leaving the surface of the stump varied directly with external sodium concentration of the medium in which the regenerating limbs were immersed. When amiloride or methyl ester of lysine, which block sodium entry, were added to the medium the stump current was quickly and greatly reduced. The data indicate that the outward regenerating currents were skin-driven. Moreover, transection of the main limb nerves did not reduce these currents, pointing to the skin rather than the nerves as the pump that drove these stump currents. The outward currents were comparable in direction, density, duration, and position to artificially imposed currents previously found sufficient to induce significant regeneration of amputated adult frog limbs. This comparison suggests that endogenous stump currents play some causal role in initiating regeneration.

- 5237 THE ELECTRICAL ENHANCEMENT OF PERIOSTEAL PROLIFERATION IN NORMAL AND DELAYED FRACTURE HEALING. (Eng.) Connolly, J. F. (Dept. Orthopaedic Surgery and Rehabilitation, Univ. Nebraska Coll. Medicine, Omaha, NB 68105); Hahn, H.; Jardon, O. M. *Clin Orthop* (124): 97-105; 1977. (31 refs)

The electrical enhancement of periosteal proliferation in normal and delayed fracture healing is discussed. During experiments in which a transverse undisplaced fracture was produced in the middle third of 70

canine radii using transfixion pins to immobilize the fracture with plaster, a constant direct current averaging 20 μ A was applied to the pins. Of 29 stimulated fractures tested within 5 wk, 10 had returned to a torque strength that was equivalent to 40% or more of normal. None of 30 unstimulated fractures achieved this strength level until wk 6 after fracture. The reaction to electrical stimulation appeared to be diffuse, irritative periosteal response. In other experiments, consistent nonunions were obtained by creating osteoperiosteal defects ranging in size from 0.5-2 cm in the mid ulna of mature dogs. A negative electrode was inserted into the defect site through holes drilled in the proximal and distal segments as close to the defect as possible. After stimulation of the proximal and distal ends with continuous 20 μ A current for up to 13 wk, the consistent result in 12 dogs was a resorption of the bone from the distal segment with no attempt to heal or obliterate the defect, regardless of its size. It was concluded that the electrical stimulation does not provoke osteoblasts to bridge bone gaps if there is no periosteum to guide and contribute cellular components to callus formation. Two case reports of the successful use of currents between 20 and 25 μ A for the treatment of patients with nonunions of the tibia are presented to illustrate the types of injury in which bone grafting procedures are liable to fail and for which electrical enhancement is a worthwhile consideration.

- 5238 TREATMENT OF CONGENITAL PSEUDARTHROSIS OF THE TIBIA WITH DIRECT CURRENT. (Eng.) Lavine, L. S. (Div. Orthopaedic Surgery, State Univ. New York, Downstate Medical Center, Brooklyn, NY 11202); Lustrin, I.; Shamos, M. H. *Clin Orthop* (124): 69-74; 1977. (22 refs)

The use of direct current for the treatment of congenital pseudarthrosis of the tibia is reported. Preliminary experiments with rabbits were conducted in which 2-4 μ A of direct current was used to heal bony defects. The model placed the anode and cathode above and below the experimental bony defect, allowing current to flow across it (current-sensitive model). This current-sensitive method was then used to treat a 14-yr-old male with congenital pseudarthrosis of the tibia. Platinum electrodes were inserted just into the medullary cavity of the tibia through drill holes, with the current path traversing bony tissue on both sides of the defect. Bony union was achieved after 4 mo of treatment. This current sensitive method was also used to treat a 5-yr-old female with neurofibromatosis and a congenital pseudarthrosis of the tibia; the method failed however. Electrical stimulation was then tried in conjunction with a bone graft, utilizing bone bank cancellous bone. The ground bone bank was placed posterior to the congenital pseudarthrosis of the tibial defect, while the electrodes were placed anterior to the defect. After continuous application of current for 4 mo, there was healing. Experience to date indicates that the best results are obtained by a combination of electrical stimulation with the addition of bone graft. The electrical stimulation is provided by two mercury cells, which

provide a total of 2.70 V. This voltage is impressed upon a series combination of a variable resistor (10^6 ohms) and the treatment area. With the electrodes in place, the resistor is adjusted to yield the desired current.

5239 RESONANT GROWTH RATE RESPONSE OF YEAST CELLS IRRADIATED BY WEAK MICROWAVES.

(Eng.) Grundler, W. (Gesellschaft fuer Strahlen- und Umweltforschung, 8042 Neuherberg, W. Germany); Keilman, F.; Froehlich, H. *Phys Letters* 62A(6): 463-466; 1977. (8 refs)

The growth behavior of microwave-irradiated yeast cultures (diploid wild strain of *Saccharomyces cerevisiae*) was monitored by visible light extinction. The temperature of the sample was 30.5-34 C, and it never varied more than ± 0.5 C during any experiment. The cultures were exposed to continuous wave microwave fields at surface intensities of 1.1-2.7 mW/cm². Over a frequency range of 41.83-41.96 GHz, multiple biological resonances were observed, with the growth rate either remaining constant or becoming enhanced or reduced at different frequencies. Increases up to 15% and decreases as large as 29% were observed in growth rate normalized to eliminate temperature effects. Careful temperature monitoring excluded a trivial thermal origin of the observed effects. The results confirm the existence of resonant influences of coherent millimeter waves on biologic properties and reveal the extreme narrowness of this response.

5240 ORIENTATION AND LINEAR DICHROISM OF CHLOROPLASTS AND SUB-CHLOROPLAST FRAGMENTS ORIENTED IN AN ELECTRIC FIELD. (Eng.)

Gagliano, A. G. (Universite Paris XI, Institut Universitaire de Technologie, Cachan, France); Geacintov, N. E.; Breton, J. *Biochim Biophys Acta* 461(3): 460-474; 1977. (28 refs)

Whole or broken spinach chloroplasts, bacterial chromatophores, and chlorophyll-protein (CP) complexes in aqueous suspensions at room temperature were oriented in externally applied electric fields. The orientation was observed by monitoring the electric field-induced linear dichroism (LD). With whole chloroplasts, a detectable LD signal was observed using 50-Hz alternating voltages as low as 2-3 V across a 0.3-cm electrode gap, and nearly complete orientation was observed at fields of 30 V/cm. The wavelength dependence of the LD signals using either orienting electric fields (E) alone or magnetic fields (B) alone were similar but opposite in sign, with E and B pointing in the same direction. The chloroplasts tended to orient in such a way that the membrane planes were parallel to E. Small subchloroplast fragments, which cannot be oriented in magnetic fields of 10,000-15,000 G but can be readily oriented in electric fields, displayed linear dichroism spectra similar to those of intact chloroplasts. The CP complexes, chromatophores, and subchloroplast fragments were best oriented using short (1-10 msec) pulsed electric

fields or approximately 3,000 V/cm. Oriented CP complexes exhibited LD maxima of the same sign at 685 and at 440 nm. The oriented chromatophores exhibited an LD spectrum of either positive or negative sign, depending on the wavelength. The orientation of particles in electric fields is suggested to be due to either or both of the following effects: the presence of a permanent dipole moment, which tends to align itself with the applied electric field; an anisotropic polarizability, which gives rise to an induced dipole moment when an external electric field is applied.

5241 TECHNOLOGY FOR THE HYPERTHERMIC TREATMENT OF LARGE SOLID TUMOURS AT 50°C. (Eng.)

Dickson, J. A. (Cancer Res. Unit, Univ. Dept. Clinical Biochemistry, Royal Victoria Infirmary, Newcastle-upon-Tyne, England); Shah, S. A. *Clin Oncol* 3(3): 301-318, 1977. (44 refs)

The use of radio frequency (RF) heating for the treatment of large experimental solid tumors is reported, and a literature review is presented. A commercially available RF heating machine operating at a crystal controlled frequency of 13.56 MHz with an output of 30 W was used. Rabbit VX2 intra-muscular carcinoma, which has many characteristics similar to human cancer, was used as the animal model test system. The tumor was heated by placing two paddle-shaped electrodes on opposite sides of the tumor-bearing limb. Tumors up to 22 ml in volume were rapidly heated to 50 C without damage to neighboring normal tissue. Among 15 VX2 tumors treated by RF heating at 47-50 C for 30 min, 10 regressed completely in 6-8 wk. Three rabbits suffered paralysis, and two rabbits had an open wound from skin damage; however, there was no increase in tumor volume. Skin breakdown leading to an open wound occurred in 2/6 rabbits when the same type of tumor was heated at 50-53 C for 15 min. Tumor regression did not occur in the remaining four rabbits, and the animals died with large tumors and metastases within 80 days of tumor inoculation. Heating methods such as waterbath, water cuff, heat pipe, and electrocoagulation did not compare favorably with the RF heating machine for controlled heating at tumor temperatures in the region of 50 C.

5242 AN AUTOMATED MEASUREMENT SYSTEM FOR DETERMINING ENVIRONMENTAL RADIOFREQUENCY FIELD INTENSITIES II. (Eng.)

Tell, R. A.; Hankin, N. N.; Nelson, J. C.; Athey, T. W.; Janes, D. E. In: *Measurements for the Safe Use of Radiation. Proceedings of an NBS 75th Anniversary Symposium held at National Bureau of Standards, Gaithersburg, MD on March 1-4, 1976.* pp. 203-213; 1976. (19 refs)

A mobile automated measurement system, used by EPA for determining environmental radio frequency (RF) field intensities, is described. The system uses a spectrum analyzer interfaced to a minicomputer for data acquisition and is contained within a van for nationwide use. Special antenna systems (active vertical monopole, orthogonal dipoles, vertical

coaxial dipoles, directional log periodic antenna, and vertical and horizontal sawtooth, planar, log periodic antennae) allow isotropic field intensity measurements in selected bands between 0.5 MHz and 10 GHz. Presently the van is being used to collect environmental data in East-coast cities. As data becomes available, more refined methods are being developed for selecting the total number and location of monitoring sites within a given metropolitan area. Initial monitoring locations are chosen on the basis of RF source distributions and population densities. As the monitoring program progresses, measurements in high density West-coast cities are planned.

- 5243 MICROWAVE BOLUSING: A TECHNIQUE FOR IMPROVING HEATING UNIFORMITY FOR MICROWAVE HYPERTHERMIA (MEETING ABSTRACT). (Eng.) Robinson, J. E. (Sch. Medicine, Univ. Maryland, Baltimore, MD 21201); McCulloch, D.; Cheung, A.; Samaras, G.; Slawson, R. G. *Med Phys* 4(4): 336; 1977. (0 refs)

A microwave analogy of radiation therapy bolus techniques was developed to alter and control the shape and size of the target and improve heating uniformity. Two direct applications of this "microwave bolus" technique were studied: (1) mono-directional far field irradiation of mammary tumors on the flanks of mice; (2) parallel opposed microwave heating by dielectrically loaded applicators operating in the transverse electromagnetic mode (TEM) mode. In the first, tumors were encapsulated in 5-cm spheres, and in the second, tumors were treated in parallel slab geometry. Improvements in thermal uniformity are described.

- 5244 ELECTRICAL STIMULATION OF HUMAN FRACTURE HEALING BY MEANS OF A SLOW PULSATING, ASYMMETRICAL DIRECT CURRENT. (Eng.) Jorgensen, T. E. (Egevangen 9, 8900 Randers, Denmark). *Clin Orthop* (124): 124-127; 1977. (10 refs)

The use of slow pulsating asymmetrical direct current for the treatment of 28 patients with tibial fractures is reported. The fractures were treated with external fixation by means of a Hoffmann apparatus, with the direct current applied to the fracture site through two electrode-screws in the Hoffmann apparatus. The stimulator used to produce the current generated a pulsating alternating current of about 1 Hz at an amplitude of about 0.7 V. A slight asymmetry in the alternating current caused the fracture to be affected by a weak pulsating direct current. The magnitude of the pulsating direct current was 40 μ A. Statistical analysis of the results obtained with 24 evaluable patients revealed a 30% acceleration in healing. An average of 2.4 mo was required to achieve clinical stability or the desired degree of stiffness as measured by mechanically stressing the tibia via the Hoffmann apparatus. A control group of patients required 3.6 mo to achieve the same degree of stiffness; the difference between experimental and control groups was highly significant ($p < 0.001$). The frequency of skin reactions

around the screws was twice as great in electrically-stimulated patients as in controls, and the intensity of the tissue reaction caused by the stimulator was such that occasionally the skin between the electrodes became erythematous and tender. Reversing the polarity of the electrodes periodically (once/wk or once/day) reduced the frequency of skin irritation. A 5-yr followup of one 84-yr-old man revealed that some of the tibial bones developed thickened cortices and that some of the comminuted fractures showed prominence of bone at the fracture. The screw canals in the bone had filled in, some with tiny exostoses. No destructive process was apparent on x-ray.

- 5245 THE INFLUENCE OF MICROWAVE RADIATION ON NORMAL AND NEOPLASTIC CELLS (ABSTRACT). (Eng.) Szmigielski, S. (Medical Acad., Warsaw, Poland); Janiak, M.; Kobus, M.; Luczak, M. *Folia Histochem Cytochem* 15(2): 164; 1977. (0 refs)

The effects of microwave radiation (3,000 MHz) of varying density (nonthermal, subthermal, and thermal) on the metabolism of normal cells and simian virus 40 (SV40) transformed fibroblasts were investigated. In one series of experiments, cells were treated with membrane-damaging substances (digitonine, phospholipase, sphingomyelinase) in subcytotoxic concentrations prior to irradiation. Non-thermal irradiation (5 mW/cm²) caused a temporary increase in cell metabolism and function. However, higher densities (20 and 40 mW/cm²) caused inhibition of both cell metabolism and culture growth; the process was more marked in the SV40-transformed cells. Cell damaging substances in subtoxic doses increased the sensitivity of cultures to subthermal and thermal microwave radiation.

- 5246 MICROWAVE HEATING PATTERNS IN SIMPLE TISSUE MODELS. (Eng.) Hand, J. W. (MRC Cyclotron Unit, Hammersmith Hosp., Ducane Road, London W12 0HS, England). *Phys Med Biol* 22(5): 981-987; 1977. (12 refs)

The effects of microwave radiation on two spherical models of differing sizes are examined theoretically. The models consisted of a spherical core of material having the electrical properties of muscle, surrounded by two spherical shells, with the inner shell having electrical properties similar to those of fat and the outer shell having properties resembling those of skin. The spheres were assumed to be in air and to be irradiated by plane waves. An examination of the distributions of heating potential along the diameters of a 40-mm diameter sphere (representative of a mouse) exposed to 2.45 GHz radiation revealed that the heating potential was distinctly nonuniform and that the maximum heating potential occurred at a point within the central core of the model. Calculations for other frequencies showed that both the position and the magnitude of the hot region depended on the frequency of the microwave radiation. At 800 MHz, for example, maximum heating still occurred in the muscle region, although it was at

a position close to the front of the sphere and its magnitude was only marginally greater than that at the front surface. Experiments with mouse cadavers rolled into spheres and irradiated with 2.45 GHz radiation confirmed that maximum heating potential occurs in the central region of the sphere. Calculations of the distribution of heating potential for a sphere of 260 mm diameter (representative of a larger animal or part of a human torso) over a frequency range of 200 MHz to 2.45 GHz revealed that the heating potential distributions had their maxima at the front surface and, in general, the heating potential decreased exponentially into the spheres. As the frequency decreased, the penetration into the sphere was greater than that predicted by a plane model. It is suggested that if a therapeutic application requires human tissue to be heated at depth, a heating potential distribution such as that produced by plane wave irradiation at 2.45 GHz is disadvantageous, since skin and subcutaneous tissues will receive more thermal energy than the region of interest.

- 5247 RESPONSE OF GALLUS CHICKS TO ELECTROSTATIC FIELDS (MEETING ABSTRACT). (Eng.) Graves, H. B. In: *The 17th Harford Biology Symposium: Developmental Toxicology of Energy-related Pollutants* held October 17-19, 1977, Richland, WA. Batelle and U.S. Energy Research and Development Admin. pp. 40; 1977. (0 refs)

The ontogeny of behavioral and electrophysiologic responses of domestic chicks to 60 Hz, high-intensity electrostatic fields were evaluated during long- and short-term exposures. Measurements included hatching times, activity patterns, oxygen consumption, heart rate, growth, and brain-wave activity. Results suggest that birds can detect an electrostatic field and that both motor development and electrophysiologic parameters are affected; however, responses are small and transient.

- 5248 EFFECT OF CONVENTIONAL AND MICROWAVE HEATING ON *PSEUDOMONAS PUTREFACTENS*, *STREPTOCOCCUS FAECALIS* AND *LACTOBACILLUS PLANTARUM* IN MEAT TISSUE. (Eng.) Crespo, F. L. (Departamento de Tecnología y Bioquímica de los alimentos, Facultad de Veterinaria, Cordoba, Spain). *J Food Protection* 40(9): 588-591; 1977. (24 refs)

The effects of conventional heating and microwave heating on selected microbial strains inoculated into sterile beef were compared. Patties (50 g) of inoculated and incubated ground beef were subjected to different temperature treatments in a conventional electric oven maintained at 176 C and in a microwave oven operating at a 2,450 MHz frequency. The final internal temperatures required to produce two-decimal reductions in *Pseudomonas putrefaciens* (Pp), *Lactobacillus plantarum* (Lp), and *Streptococcus faecalis* (Sf) were 51, 57, and 62 C, respectively, for conventional heating and 63, 78, and 74 C, respectively, for microwave heating. To achieve four-decimal reductions in Pp,

Lp, and Sf final internal temperatures of 57, 62, and 70 C, respectively, were required for conventional heating, and temperatures of 73, 87, and 81 C, respectively, were required for microwave heating. The data indicate that microwave heating to the same internal endpoint temperatures was less effective than conventional heating for microbial destruction. The difference in heat sensitivity between conventional and microwave heat was most apparent for Lp, which was not particularly heat resistant when heated by conventional means.

- 5249 INFLUENCE OF ROTATING MAGNETIC FIELD OF 200 GAUSS ON SPLENECTOMIZED MICE. (Cae.) Petz, R. (Ustav hematologie a krevni transfuze, 128 20 Prague 2, U nemocnice 1, Czechoslovakia); Viktora, L. *Vnitř Lek* 23(2): 141-145; 1977. (14 refs)

The hematologic effects of exposure to rotating magnetic field (180-200 G, 4-5 rpm, >5 wk was studied in splenectomized SPF-ICR mice. Unexposed splenectomized and intact mice were used as controls. Exposure to the magnetic field caused significant increase in the erythrocyte count during the first 3 wk, and the leukocyte count increased even after the 5th wk. The thrombocyte count decreased but normalized shortly after exposure, while the reticulocyte count increased throughout the experiment. The investigation of hematopoiesis in the bone marrow at the end of the exposure revealed enhanced erythropoiesis and lymphopoiesis, depression of the granulocytopenia, and reticulocyte formation. The findings confirm the stimulating effect of the magnetic field on hematopoiesis and indicate that the effect of relatively weak magnetic fields is more pronounced in splenectomized animals than in intact ones.

- 5250 OCULAR MEDICAL SURVEILLANCE ON MICROWAVE AND LASER WORKERS. (Eng.) Hathaway, J. A. (US Army Environmental Hygiene Agency, Aberdeen Proving Ground, MD 21010); Stern, N.; Soles, E. M.; Leighton, E. *J Occup Med* 19(10): 683-688; 1977. (14 refs)

A statistical analysis of over 800 medical surveillance ocular examinations on microwave and laser workers is presented. The number of years of work with microwave equipment varied from less than 1 yr to 35 yr. Of 823 workers subjected to ocular examinations, 705 were microwave workers. The results of slit-lamp examinations were analyzed using multiple regression statistical techniques to determine the influence of microwave and laser exposures on the presence or absence of opacities, vacuoles, and posterior subcapsular iridescence. No lenticular or retinal defects were noted that could be attributed to work with either microwave or laser radiation. Increased incidences of minute lenticular defects were noted with increasing age. A high variability in the recording of such defects at different locations was attributed to differences in the subjective evaluation of the individual

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examiners. It is concluded that periodic medical surveillance of microwave and laser workers is nonproductive, and suggestions are made to limit medical surveillance for these workers to preassignment, postaccident exposure, and termination eye examinations.

5251 TECHNIQUES IN MICROWAVE AND RADIOFREQUENCY HEATING OF TISSUES (ABSTRACT). (Eng.)

Hand, J. W. (Hammersmith Hosp., London W12 0HS, England). *Int J Radiat Biol* 32(4): 381; 1977. (0 refs)

The band of frequencies in the electromagnetic spectrum used in heating tissue at depth is discussed. The methods used to heat tissues are described, and the advantages and disadvantages of such methods outlined. The possibility of producing microwave-induced internal hot-spots in a target whose dimensions are comparable to the wavelength of the radiation and the relevance of this to the heating of small animals are discussed. The advantages of microwave contact applicators are outlined, and two such devices described. Some of the problems associated with temperature measurement in the presence of electromagnetic fields are stated, and new kinds of thermometers that enable reliable temperature measurements to be made in such an environment are briefly described.

5252 STUDIES OF ENHANCED BONE HEALING VIA ELECTRICAL STIMULI: COMPARATIVE EFFECTIVENESS OF VARIOUS PARAMETERS. (Eng.) Hassler, C. R.

(Battelle, Columbus Lab., 505 King Ave., Columbus, OH 43201); Rybicki, E. F.; Diegle, R. B.; Clark, L. C. *Clin Orthop* (124): 9-19; 1977. (16 refs)

A rabbit calvarium model was used for studying the effects of applied electric currents on osseous tissue. Total currents ranging from 3-1,400 μ A were applied using brush-type electrodes of either platinum or tantalum oxide. Direct current as well as unidirectional rectangular pulses, sine waves, and bidirectional rectangular pulses were used with pulse repetition rates or frequencies ranging from 1-60 Hz. The standard stimulation protocol was of 3-wk duration. There was no specific advantage of direct current over alternating currents at frequencies of up to 60 Hz, and there was no clear-cut advantage of one repetition rate over another. A plot of percent bone growth versus calculated power for the cathode, as determined by densitometry measurements of the postnecropsy radiograph, revealed a rapid increase in bone growth with increases in power dissipation; this increase reached a maximum at a power dissipation of about 35 μ W. After values of about 100 μ W, bone growth approached control levels. Radiographic densitometry results at the anode revealed a decreasing healing rate with increasing power dissipation. Experiments where the stimulation protocol was shortened from the normal 3-wk healing period revealed that when animals were stimulated for only the first 7 days of the experiment, healing was well below control.

Also, applying the same amount of electrical energy within a shorter period of time did not produce the same beneficial effects of the 3-wk protocol. Experiments with tantalum oxide electrodes illustrated that augmented healing of bone can be produced when electrochemical reactions are reduced. However, higher power dissipations appear to be required with tantalum oxide electrodes than with platinum electrodes to effect the same degree of healing.

5253 MICROWAVE DIELECTRIC PROPERTIES OF TISSUE: SOME COMMENTS ON THE ROTATIONAL MOBILITY OF TISSUE WATER. (Eng.) Schwan, H. P.

(Dept. Bioengineering, Univ. Pennsylvania, Philadelphia, PA 19174); Foster, K. R. *Biophys J* 17(2): 193-197; 1977. (12 refs)

Microwave dielectric permittivity and conductivity data for biologic tissue are reviewed over the frequency range of 0.1-10 GHz. The high frequency dielectric properties of muscle predict that the tissue water exhibits a Debye dipolar absorption centered at 20 GHz at room temperature, identical to that of pure water. Increases in tissue conductivity of canine muscle, skin, and liver observed at frequencies above 1 GHz correspond to a free water content of roughly 70% of the tissue weight, comparable to the known water content of these tissues. From a dielectric point of view, the tissue is apparently equivalent to a suspension of nonconducting solid in ordinary bulk water at these high frequencies, contradicting the hypothesis that most of the cell water has motional properties greatly different from those of pure liquid.

5254 DIFFERENTIAL RESPONSE TO ELECTRICAL STIMULATION: A DISTINCTION BETWEEN INDUCED OSTEOGENESIS IN INTACT TIBIAE AND THE EFFECT ON FRESH FRACTURE DEFECTS IN RADII. (Eng.) Harris, W. H.

(266 Beacon St., Boston, MA); Moyer, B. J.-L.; Thrasher, E. L.; Davis, L. A.; Cobden, R. H.; MacKenzie, D. A.; Cywinski, J. K. *Clin Orthop* (124): 31-40; 1977. (26 refs)

The effects of continuous direct current (CDC) stimulation (20 μ A) on osteogenesis in intact tibia and on fresh fracture defects in radii of experimental animals were investigated. Studies on osteogenesis in the medullary canal of intact tibia in young and old rabbits showed that the insertion of a non-activated electrode resulted in osteogenesis and that osteogenesis induced by the electrical current exceeded that induced by the dummy electrode. Both young and mature rabbits responded similarly. In mature rabbits, stainless steel electrodes were more effective than platinum. In dogs, an active platinum cathode induced significantly more bone than a dummy platinum electrode. The spontaneous healing capacity and/or healing rate were determined for three different fresh surgically-created defects in the proximal radius of mature mongrel dogs, and the effect of electrical stimulation on these three models was evaluated and compared with the behavior of the contralateral radius.

containing the same defect. In a 0.5-mm transverse gap in the radius, which was not immobilized and which did not spontaneously unite, electrical stimulation did not induce a greater incidence of healing. In a 10-mm defect immobilized with a plate and screws, which regularly united spontaneously, no x-ray evidence of acceleration of fracture healing was noted. No evidence of electrically-stimulated osteogenesis was found in two dogs with a plate-and-screw immobilized 20-mm defect, which did not unite spontaneously.

- 5255 BIOLOGICAL EFFECTS OF ELECTROMAGNETIC RADIATION (RADIOWAVES AND MICROWAVES)--EURASIAN COMMUNIST COUNTRIES, MARCH 1976. (Eng.) Adams, R. L.; Williams, R. A. (Dept. Defense, Defense Intelligence Agency, Washington, DC 20301). [available from the Dept. Defense, Defense Intelligence Agency, Washington, DC 20301, Document No. DST-1810 S-074-76]. (0 refs)

Research being conducted by Eurasian Communist countries on the biologic effects of radiowave and microwave radiation is outlined. Most of the research involves animals or in vitro evaluations, but active programs of a retrospective nature designed to evaluate the effects on humans are also being conducted. Major systems, system components, or processes currently under study in the Eurasian Communist countries include the blood, cardiovascular system, cells, central nervous system, digestive system, glandular system, metabolic effects, reproductive system, visual system, and internal sound perception. The last of these areas of research has potential for the development of a number of antipersonnel applications. Sounds and possibly even words, which appear to be originating intracranially, can be induced by signal modulation at very low average power densities. Animal experiments reported in the open literature have demonstrated the use of low-level microwave signals to produce death by heart seizure or by neurologic pathologies resulting from crossing the blood-brain barrier; the bulk of research being done in this area is in the USSR. Evaluation of the research being conducted by the Eurasian Communist countries is often difficult because details of exposure in terms of frequency, duration, and intensity are quite variable and sometimes poorly reported. The Eurasian Communist investigators tend to place greater importance on the potential nonthermal effects of nonionizing radiation than do their Western counterparts, and information regarding the precise nature of the exposure under consideration is often difficult to establish. Studies that report on nonthermal effects deal largely with subjective responses, relying on reports of headache, sleepiness, loss of appetite, and the like. The presence of nonthermal effects, in addition to thermal effects, at higher intensities has also been postulated by Eurasian Communist investigators, but no detailed investigative support for this possibility has been noted. No Eurasian Communist research activity has been identified that can clearly or directly relate to any military offensive weapons program.

- 5256 THERMAL RESPONSES TO HIGH-FREQUENCY ELECTROMAGNETIC RADIATION FIELDS. (Eng.) Frazer, J. W.; Merritt, J. H.; Allen, S. J.; Hartzell, R. H.; Ratliff, J. A.; Chamness, A. F.; Detwiler, R. E.; McLellan, T. (Radiation Physics Branch, Radiobiology Div., USAF Sch. Aerospace Medicine, Aerospace Medical Div., AFSC, Brooks Air Force Base, TX 78235). 19 pp.; 1976. [available through National Technical Information Services, Springfield, VA 22161, Document No. AD A032179]. (17 refs)

Male rhesus monkeys were exposed to high frequency (26 MHz) radiation in a rectangular coaxial transmission line for 6 hr/day over a 5-day wk at power levels of 500, 750, and 1,000 mW/cm² to assess their thermal response to such exposures. Experiments were run where the 6-hr exposures were interrupted every 30 min for rectal temperature measurements, and where the 6-hr exposures were uninterrupted with rectal temperatures obtained immediately before and after irradiation. An immediate rise in skin and rectal temperature, with subsequent cooling, was noted. Rectal temperature reached an equilibrium after about 1.5 hr of exposure. This equilibrium was maintained throughout the remainder of the exposure period. At power levels of 500, 750, and 1,000 mW/cm², the rectal cooling rates were 0.36, 2.64, and 3.54 C/hr; the corresponding skin cooling rates were 1.74, 2.46, and 1.75 C/hr, respectively. Such cooling rates are sufficient to bring the core and skin temperature to normal values in an hour or less, indicating that thermoregulatory mechanisms were not impaired by 6 hr of irradiation even at the 1,000 mW/cm² level and that the monkeys were able to easily dissipate the heat load following cessation of radiation.

- 5257 MAGNETIC FIELD EFFECTS ON RADICAL PAIR INTERMEDIATES IN BACTERIAL PHOTOSYNTHESIS. (Eng.) Blankenship, R. E. (Dept. Biochemistry, Univ. Washington, Seattle, WA 98195); Schaafsma, T. J.; Parson, W. W. *Biochim Biophys Acta* 461(2): 297-305; 1977. (27 refs)

The effects of magnetic fields on the formation and decay of excited states in the photochemical reaction centers of *Rhodospseudomonas sphaeroides* (strains R-26 and 2.4.1) were investigated. In chemically reduced reaction centers, a magnetic field decreased the fraction of the transient state (PF) that decays by way of the bacteriochlorophyll triplet state (PR). At room temperature, a 2-kG field decreased the quantum yield of PR by about 40%. In carotenoid-containing reaction centers, the yield of the carotenoid triplet state, which forms via PR, was reduced similarly. The effect of the field depended monotonically on field strength, saturating at about 1 kG. The effect decreased at lower temperatures when the yield of PR was higher. Magnetic fields did not significantly affect the formation of the triplet state of bacteriochlorophyll in vitro, the photooxidation of P-870 in reaction centers at moderate redox potential, or the decay kinetics of states PF and PR. The magnetic field effects support the view

that state P^F is a radical pair which is born in a singlet state but undergoes a rapid transformation into a mixture of singlet and triplet states.

- 5258 PERFORMANCE AND SAFETY STANDARDS FOR ELECTROSURGICAL DEVICES. (Eng.) Emergency Care Research Institute (Emergency Care Res. Inst., 5200 Butler Pike, Plymouth Meeting, PA 19462). 156 pp.; 1977. [available through National Technical Information Services, Springfield, VA 22161, Document No. PB-265 893]. (refs)

The feasibility of testing and achieving requirements of proposed performance and safety standards for electrosurgical devices was studied. Three commercial electrosurgical units were examined; the units operated over frequencies ranging from 500 kHz to 3 MHz at maximum power outputs of 65-375 W in one or more of the following modes: cutting, coagulation, blending, hemostasis. The test results indicated that the requirements of the proposed standards could be tested in commercially available units. All units met a great majority of the requirements of the standard; however, the standard proposed certain requirements that call for features that were not universally incorporated in present units. Examples included audible indicators of activation and a prohibition of multiple-energized active electrodes. Failures to conform to the proposed performance requirements involved the limitation on electrosurgical leakage power from the dispersive electrode, sustained short-circuit operation, and provision for electromagnetic compatibility. In addition to the testing information, lists of invited reviewers of the drafts of proposed standards, of persons requesting copies for review, of attendees at public review meetings, and of persons and organizations submitting written comments following review are also provided. A list of electrosurgical device manufacturers is also included, and extensive bibliography is given.

- 5259 HEMATOLOGICAL AND BIOCHEMICAL EFFECTS OF ELF FIELDS. (Eng.) Sheppard, A. R.; Eisenbud, M. In: *Biological Effects of Electric and Magnetic Fields of Extremely Low Frequency*. (New York: New York Univ. Press): pp. (5) 1-44; 1977. (64 refs)

Studies on the hematologic and biochemical effects of direct current (DC) and alternating current (AC) electromagnetic fields in the extremely low frequency range are reviewed. Evidence that environmentally relevant field strengths can affect blood composition, biochemical synthesis, or metabolism comes from a few, scattered experiments. Reports of an AC electric field effect include the following: changes in plasma protein and steroid levels as well as in body weight of rats exposed continuously at 15 kV/m (60 Hz), alterations in white blood cell counts observed in mice and rats at 100 kV/m (50 Hz) and in humans at 15 and 20 kV/m, and altered calcium efflux from chick and cat brains exposed to a field (in air) of 10 V/m or

56 V/m (6 and 16 Hz). Magnetic field effects include elevations of serum triglyceride levels in men exposed for 10 or 22 hr at 1 G (45 Hz), metabolic decreases in nerve cell organelles (synaptosomes) exposed to 50 and 100 G (60 Hz), and steroid changes in monkeys exposed to 200 G (DC). Other biochemical effects reported involve the influence of electric fields on brain tissue, cell organelles, frog red blood cells, and fibroblast cells in cultures; however, these effects were observed at field strengths much greater than those encountered environmentally. There are many reports illustrating that DC, and perhaps AC, currents have an important role in bone growth and repair. There is also one report of tumors related to electrical stimulation of bone. With the exception of bone studies and, to a lesser extent, neural studies, none of the above areas has been adequately investigated. The reported effects have not yet been corroborated by an independent replication, nor has experimental work advanced to the point where response thresholds, a dose-response relation, or frequency dependence are known.

- 5260 PHYSIOLOGICAL AND BEHAVIORAL EFFECTS IN NON-HUMAN SPECIES. (Eng.) Sheppard, A. R.; Eisenbud, M. In: *Biological Effects of Electric and Magnetic Fields of Extremely Low Frequency*. (New York: New York Univ. Press): pp. (7) 1-45; 1977. (66 refs)

Studies on physiologic and behavioral effects produced in experimental animals exposed to electric and magnetic fields in the extremely low frequency range are reviewed. Topics covered include central nervous system effects in monkeys and cats; the effect of external electrical fields on internal electric fields in animal brain tissue; the effect of combined electric and magnetic field on behavioral and physiologic processes in monkeys; electroencephalographic and electrocardiographic changes in animals exposed to 100 kV/m, 50-Hz electric fields; electric field effects on neurons; the effect of electric and magnetic fields on the mitotic cycle in slime mold; the effect of electric fields on mouse fertility; the effects of alternating electric fields (60 Hz) on the activity of caged mice; magnetic field effects on the psychological behavior of rats, electric and magnetic field effects on animal migration, navigation, and communication; electric field effects on marine animals; the effects of electromagnetic fields on the conditioned behavior of pigeons and rats; the effects of electric or magnetic fields on the growth and development of chicks; patterns of electrical activity during early embryological development in animals; multigenerational studies of rats exposed to combined electric and magnetic fields; the effects of extremely low frequency fields on mutagenesis in *Drosophila* and *Escherichia coli*; the effect of low level direct currents on nerve tissue regeneration; and electric field effects on amoeba.

- 5261 PHYSIOLOGICAL AND BEHAVIORAL EFFECTS IN HUMANS. (Eng.) Sheppard, A. R.; Eisenbud, M. In: *Biological Effects of Electric and Magnetic Fields of Extremely Low Frequency*. (New York: New York Univ. Press): pp. (6) 1-23; 1977. (28 refs)

Studies on human physiologic and behavioral changes associated with exposure to extremely low frequency electric and magnetic fields are reviewed. Topics covered include perception of low level electric and magnetic fields; perceptual, behavioral, and physiological responses in a magnetic field; psychomotor function and cognitive skills in magnetic fields; the effects of zero magnetic fields; physiologic changes in electrical substation workers; electric discharge effects; effects on biologic (circadian) rhythms; correlations between human behavior and geomagnetic storms; and the phenomenon of dowsing in relation to magnetic perception. A study on the perception of low level electric and magnetic fields by humans indicates that human reaction times may be sensitive to external electric fields in the frequency range of 2-12 Hz at a field strength of 4 V/m. In a zero magnetic field experiment where human subjects were exposed to a magnetic field attenuated to 1/1,000 of the geomagnetic field for a period of 10 days, flicker fusion threshold was found to decrease in frequency linearly with time during the test period. Soviet studies on electric substation workers in a 400-500 kV switchyard (50 Hz) revealed physiologic effects manifested by vagotonic changes in the cardiovascular system, a weakening of thermal regulation processes, a lowering of resistance to the action of electric currents, changes in the functional mobility of the neuromuscular apparatus of the hand, and a weakening of neurodynamic processes in the cortex of the brain. In terms of behavioral changes, a statistical correlation has been found between admissions to psychiatric hospitals and changes in the geomagnetic field.

- 5262 SOIL MICROORGANISM POPULATION DYNAMICS IN WEAK ELF ELECTROMAGNETIC FIELDS. (Eng.) Rosenthal, G. M. (Biological Sciences Collegiate Div., Univ. Chicago, Chicago, IL 60637). 36 pp.; 1976. [available through National Technical Information Services, Springfield, VA 22161, Document No. AD A035957]. (4 refs)

Soil samples from a pine plantation and a meadow were exposed in the laboratory to an electric field of 1 V/m (root mean square) and a magnetic field of 1 G (root mean square) at a frequency of 60 Hz for up to 16 wk. The microbial population of soil samples exposed to extremely low frequency (ELF) fields was periodically compared with that of soil samples not exposed to the ELF field that served as the control for this study. Soil samples were assayed at 0, 2, 4, 8, and 16 wk for total number of aerobes, anaerobes, and fungi as well as for microorganisms having specific biochemical functions such as nitrification, denitrification, urea decomposition, cellulose decomposition, and sulfate reduction. The results indicated no significant

effects of the extremely low frequency fields on the concentration of microorganisms in the soil. Differences in microorganism concentration that were observed could be ascribed to the soil type and sampling variations.

- 5263 THE PROBLEM OF CLINICAL HYPERTHERMIA. (Eng.) Nelson, A. J. (Radiotherapy Centre, 21 McCourt St., Leederville, Western Australia); Holt, J. A. *Australas Radiol* 21(1): 21-30; 1977. (18 refs)

The use of very high frequency (433 MHz) radiation-induced hyperthermia in conjunction with other treatment modalities for the management of various types of human cancers is reported. In a study of 27 patients with secondary cancer in the bone (21 breast cancers, 5 prostate cancers, and 1 Hodgkin's disease) where very high frequency (VHF) radiation was used in combination with chemotherapy or radiotherapy, all patients were relieved of pain after the first treatment, and all but one patient showed improvement in well being and weight gain. Another study involving the use of VHF hyperthermia in combination with ionizing radiation (average, 2,200 rads in 4-5 wk) for the treatment of 12 patients with liver metastases revealed that hyperthermia in combination with individual doses of 50-80 rads of radiation resulted in an enhancement effect equivalent to 200 rads or more. All patients had complete and fairly rapid pain relief. The liver decreased in size during the course of treatment and was subsequently undetectable by clinical palpation in 10 cases. Seven patients survived 3-18 mo (average, 10 mo). A study involving the use of VHF-induced hyperthermia in combination with radiation for the treatment of 52 patients with advanced ear, nose, and throat cancer revealed that hyperbaric radiotherapy was twice as effective as conventional supervoltage therapy in obtaining survivals at 1 and 2 yr as well as in achieving primary clearance of the tumor and in maintaining recurrence-free survival. Whereas the average dose of conventional supervoltage radiation to achieve similar results was 6,000 rads in 6 wk, only 4,800 rads over 8 wk was needed in conjunction with VHF-induced hyperthermia. This latter combination resulted in complete healing in 94% of the patients.

- 5264 EXPOSURE OF JAPANESE QUAIL EMBRYOS TO 2.45-GHZ MICROWAVE RADIATION DURING DEVELOPMENT. (Eng.) McRee, D. I. (Nat'l. Inst. Environmental Health Sciences, Post Office Box 12233, Research Triangle Park, NC 27709); Hamrick, P. E. *Radiat Res* 71(2): 355-366; 1977. (17 refs)

Japanese quail embryos were exposed during the first 12 days of development to 2.45 GHz microwave radiation at an incident power density of 5 mW/cm² and a specific absorption rate of 4.03 mW/g. When the temperature of the exposure environment was 37°C (the optimum hatching temperature) 93% of the quail embryos were killed. This result can be explained by the increase in temperature of the

embryos to 39.5-40 C, since this temperature was sufficient to kill control embryos as well. When the developing embryos were exposed under the same conditions in an environment maintained at a temperature of 35.5 C, no adverse effects on the development of quail were observed. No gross deformities were observed in the exposed quail when examined and sacrificed at 24-36 hr after hatching. No significant changes in total body weights or weights of the heart, liver, gizzard, adrenal gland, or pancreas were observed in the neonates from eggs exposed to microwaves. In terms of hematologic effects, no statistically significant changes in hematocrit, total white blood cells, red blood cells, lymphocytes, heterophils, basophils or eosinophils were measured. A statistically significant increase in hemoglobin (4%) and a decrease in monocytes were observed, however, in microwave-exposed quail. The importance of these changes on the viability of the neonate quail is not known.

- 5265 THE DESIGN OF A MONOPOLE RADIATOR TO INVESTIGATE THE EFFECT OF MICROWAVE RADIATION IN BIOLOGICAL SYSTEMS. (Eng.) Bigu-del-Blanco, J. (Anatomy Dept., Queen's Univ., Kingston, Ontario, Canada); Romero-Sierra, C. *J Bioeng* 1(3): 181-184; 1977. (6 refs)

The design of a microwave monopole radiator is described. The monopole radiator is essentially a stainless steel hollow hypodermic needle that allows both for the irradiation of deep biological structures by simple needle injection and for the simultaneous chemotherapeutic treatment of tissue. The applicator is connected to a low power, frequency-tunable microwave generator. The microwave signal can be modulated, if required, either internally or externally. Monopole impedance matching to the surrounding tissue is attained by means of a slide-screw tuner placed between the monopole and the rest of the microwave circuitry. Experiments involving both relatively large rabbit specimens and saline solutions irradiated at a frequency of approximately 10 GHz gave very similar results, within experimental error, in terms of normalized microwave reflected power measurements. Provided that a reasonable matching (power transfer) between the monopole and tissue occurs, no undesirable effects such as tissue burning at the tissue-monopole interface will occur.

- 5266 EXTREMELY LOW FREQUENCY ELECTRIC FIELD INDUCED CHANGES IN RATE OF GROWTH AND BRAIN AND LIVER ENZYMES OF RATS. (Eng.) Novak, J. J.; Sohler, A.; Reisberg, R. B.; Coyne, H.; Straub, K. D.; McKinney, H. (Dept. Surgery, Temple Univ. Sch. Medicine, Philadelphia, PA 19140). 17 pp.; 1976. [available through National Technical Information Services, Springfield, VA 22161, Document No. AD A035959]. (23 refs)

Male Sprague Dawley rats were exposed to 45-Hz vertical electric fields varying from 0.1-100 V/m (root mean square) over periods of 30-40 days. The

experiments were conducted in especially equipped, air-conditioned railroad cars that provided shielding from ambient extremely low frequency fields. The exposed rats gained weight at rates of 20-30% slower than control rats and had less abdominal fat deposits than controls. A subcortical neuron effect was evidenced by a consistent decrease in activity of the neuronal enzyme choline acetyltransferase in the brainstem of rats exposed to the 45-Hz fields; cerebral levels of this enzyme were unchanged. Adrenal weights were unchanged in exposed rats, but the liver enzyme, tryptophan pyrrolase, was elevated in many, possibly indicating that the extremely low frequency fields were able to produce a low level of stress response in the rats. Irradiated rats exhibited normal activity and eating and drinking behavior during maintenance in these fields.

- 5267 HIGH-VOLTAGE ELECTRIC FIELD COUPLING TO HUMANS USING MOMENT METHOD TECHNIQUES. (Eng.) Spiegel, R. J. (Southwest Res. Inst., San Antonio, TX 78284). *IEEE Trans Biomed Eng* 24(5): 466-472; 1977. (15 refs)

A numeric procedure is developed to calculate induced current and normal electric field distributions on humans situated at various positions in the right-of-way of a 765-kV transmission line. The numeric technique was based on the method of moments in which the human body is modeled as a collection of straight cylindrical segments with lengths and radii comparable to that section of the body being modeled. It was shown that for a man standing on the ground at a place where the vertical electric field was maximum, the induced electric fields on the hands and top of the head (150 kV/m) were of the same order of magnitude as the electric field recognition level (236 kV/m). Therefore, the electric fields were large enough to possibly be perceived by the person. For an unprotected lineman located 1.5 m from an energized conductor, the induced electric fields on his hands, feet, and head were of the same order of magnitude as the recognition level also. However, the induced field (1,000 kV/m) on his hand nearest to the energized conductor was about half that of the corona-forming level (1,968 kV/m). The unprotected lineman can be expected to have induced field levels on his hands large enough to be felt, and these induced field levels may be of sufficient magnitude to produce a corona at the ends of the finger tips.

- 5268 GALVANOTROPIC ORIENTATION OF GOLDFISH (*CARASSIUS AURATUS*). (Eng.) Wolf, D. J. (Ph.D. dissertation, Graduate Coll. Univ. Illinois at Urbana-Champaign, 1976); 186 pp. [available from Xerox Univ. Microfilms, Ann Arbor, MI 48106, Order No. 77-9243]. (71 refs)

Studies on the galvanotropic orientation of goldfish (*Carassius auratus*) are reported. Goldfish oriented toward the cathode at low intensities and toward the anode at high intensities following 15 sec of direct

current stimulation. The precision or orientation was a linear function of stimulus intensity. The partition of neurosensory control over goldfish galvanotropic orientation reflected the biphasic character of the behavior. A mechanism dependent on the intact spinal cord controlled the cathodic orientation seen at low intensities. The anisotropic electrical properties of vestibular sense cell activity appeared to be related to anodic orientation at high intensities. The precision of anodic orientation of bilaterally labyrinthectomized fish was significantly poorer than that of intact animals or animals with large brain ablations. Bilateral irrigation of the otic canals with local anaesthetic solution also produced a long lasting deficit of anodic orientation precision. *Carassius auratus* is not electrosensitive in the ordinary sense; the threshold for galvanotropic orientation of goldfish is about 0.1 V/cm, or roughly 1,000,000 times higher than that for truly electrosensitive species. An estimate of the current through a large fish (15 cm) in tap water at a tank voltage of 20 V was roughly 2.0 mA in the present studies (using 1,274 ohm/cm as the specific resistivity of the fish). If the cross section of the labyrinthine organs is about 1% of the cross section of the fish, then a current of 2.0 mA through the animal corresponds to about 20.0 μ A through the labyrinth. Since reliable reactions were seen at somewhat lower tank voltages, it is concluded that labyrinth currents of a few μ A may evoke galvanotropic orientation.

- 5269 EXPERIMENTAL AND THEORETICAL DETERMINATION OF ABSORBED MICROWAVE DOSE RATE DISTRIBUTIONS IN PHANTOM HEADS IRRADIATED BY AN APERTURE SOURCE. (Eng.) Ho, H. S. (Health, Education, Welfare, Public Health Service, Food & Drug Admin., Bureau Radiological Health, Div. Biological Effects, 5600 Fishers Lane, Rockville, MD 20852); Faden, J. *Health Phys* 33(1): 13-21; 1977. (7 refs)

A thermographic technique was used to determine absorbed microwave energy distribution in phantom monkey and human heads irradiated by a 2,450-MHz aperture source. Brain tissue spheres simulating both a monkey (3.3 cm radius) and a human head (7.0 cm radius) were used along with a bone and brain tissue equivalent geometric model of a monkey head. Maximum power (up to 100 W) was applied to the aperture source for 30 sec; and then one-half of the model was quickly (within 5 sec) placed in front of a thermographic camera for polaroid picture taking (within 5 sec). Cross-sectional temperature rise patterns for both the 7-cm radius and 3.3-cm radius brain spheres were in qualitative agreement with previous theoretic calculations. The temperature rise patterns in the phantom monkey head were similar to the pattern of the 3.3-cm brain sphere. However, the pattern in the monkey was more irregular. Temperature rise and absorbed dose rate patterns of the spheres and the phantom monkey heads were drastically different from heating patterns obtained with a plane wave source. The calculated high concentration of absorbed energy in the center of a 3.3-cm radius brain sphere resulting from a plane wave source was not observed

in the aperture-heated cases. Nevertheless, penetration of microwave energy into the phantom monkey head was sufficient to cause heating in the brain region. It is expected that by changing the aperture size or the radiation frequency, the pattern of microwave absorption can be modified.

- 5270 EXTREMELY LOW FREQUENCY (ELF) VERTICAL ELECTRIC FIELD EXPOSURE OF RATS: IRRADIATION FACILITY. (Eng.) Mathewson, N. S.; Oliva, S. A.; Oosta, G. M.; Blasco, A. P. (Armed Forces Radiobiology Res. Inst., Defense Nuclear Agency, Bethesda, MD 20014). 68 pp.; 1977. [available through National Technical Information Services, Springfield, VA 22161, Document No. AD A035955]. (12 refs)

An extremely low frequency (ELF) vertical electric field irradiation facility consisting of six identical exposure chambers is described. The facility was developed for biological research related to the United States Navy's proposed ELF communications system, which is designed to establish worldwide submarine fleet communications. The facility is designed to study the possible bioeffects of ELF on 96 rats equally divided among the six exposure chambers and individually housed in specially modified nonmetallic cages. These cages were designed to minimally perturb the exposure field and to provide accurate means to measure food and water consumption. Each exposure chamber could be independently operated up to field strengths of 1,000 V/m (root mean square) at any sinusoidal ELF frequency. At 45 Hz, the frequency chosen for this research, chamber cross-talk is less than -60 dB, and the vertical electric field uniformity within the exposure area is within $\pm 5\%$.

- 5271 IN VITRO AND IN VIVO INHIBITION OF VIRUS MULTIPLICATION BY MICROWAVE HYPERTHERMIA. (Eng.) Szmigielski, S. (Center for Radiobiology and Radioprotection, Warsaw, Poland); Luczak, M.; Janiak, M.; Kobus, M.; Laskowska, B.; de Clercq, E.; de Somer, P. *Arch Virol* 53(1/2): 71-77; 1977. (19 refs)

The effects of microwave hyperthermia (41 and 43 C) on virus multiplication were investigated in vitro (herpes simplex virus type 1 (HSV-1)-infected primary rabbit kidney cultures) and in vivo (mice infected with HSV-1 or vaccinia virus). Microwave irradiation was performed at a frequency of 3 GHz. Animals were irradiated at a mean field power density of 40 mW/cm² for 2 hr daily; for cell culture experiments, the field power density was regulated so that the temperature of the culture medium could be maintained at 41 or 43 C during the irradiation period. In vitro, hyperthermia applied for 3 or 12 hr after infection led to a marked decrease in virus yield in cell cultures, with heating at 43 C inhibiting virus multiplication to a greater extent than heating at 41 C. Heating of the cells for 3 hr prior to infection was without effect, and prolonged hyperthermia over the whole postinfection period

(72 hr) seriously impaired cell viability. In mice inoculated intranasally with HSV-1, microwave hyperthermia applied immediately after infection resulted in a significant decrease in the mortality rate ($p < 0.001$). Microwave hyperthermia applied immediately after vaccinia virus infection in mice led to a significant decrease in the number of tail lesions ($p < 0.001$). Irradiation prior to infection or delayed until 3 days after virus challenge did not exhibit an appreciable effect. The data suggest that microwave hyperthermia interferes directly with the virus multiplication cycle both in vitro and in vivo.

- 5272 EFFECT OF MICROWAVE OR WATERBATH HYPER-
THERMIA ON TUMOR GROWTH. (Eng.) Sparks,
F. C. (VA Hosp., Sepulveda, CA); Breeding, J. H.
Surg Forum 28: 141-143; 1977. (4 refs)

The effect of whole-body microwave hyperthermia versus that of whole-body waterbath hyperthermia on local tumor growth in 10-wk-old BALB/c mice was investigated. At 14 days after subcutaneous inoculation with line 26 colonic carcinoma, a total of 24 mice were divided randomly into three groups to receive either no treatment (controls) or hyperthermia (41.5°C for 60 min), which was produced either by microwave heating (2.45 GHz) or by immersion to the neck level in a waterbath. At 16 days after tumor implantation, the mean tumor volume in control mice had increased by 56% as compared with 32% ($p < .05$) for microwave-treated mice and 24% ($p < .05$) for waterbath-treated mice. At 23 days after tumor implantation, eight of eight mice treated with microwaves ($p < .05$) and seven of eight mice treated by waterbath immersion ($p < .05$) were alive compared with three of eight survivors in the control group. The effects of hyperthermia on tumor size and animal survival were transient. It is concluded that the effect of whole-body hyperthermia on tumor growth and animal survival was achieved equally well by either waterbath or microwave radiation.

- 5273 EDITORIAL COMMENT: BIOELECTRICAL EFFECTS
ON BONE AND CARTILAGE. (Eng.) Brighton,
C. T. (No affiliation given). *Clin Orthop* (124):
2-4; 1977. (0 refs)

Topics covered at a symposium on the effects of electrical stimulation on bone and cartilage are outlined. Both laboratory and clinical studies involving different electrical parameters, different electrode materials, and different application techniques are discussed. Specific investigations described include a comparison of constant direct current to various pulsed currents in a rabbit calvarium model; an evaluation of the application of constant direct current to various bone and periodontal defects in animals; the use of electret film to induce callus formation in experimental animals; clinical studies on the application of constant direct current to nonunions, congenital pseudoarthroses and fresh fractures; the treatment of tibia fractures with asymmetrical pulsed direct

current using stainless steel electrode-screws; and the treatment of patients with nonunions and congenital pseudoarthroses using electromagnetic fields pulsed at an extremely low frequency.

- 5274 THE CLASSIC FUNDAMENTAL ASPECTS OF FRACTURE
TREATMENT. (Eng.) Yasuda, I. (No affiliation given). *Clin Orthop* (124): 5-8; 1977. (1 refs)

The role of electricity in callus formation is discussed. Experiments investigating the production of electricity by bone under mechanical stress are reviewed, and it is concluded that force leads to callus formation through the production of electricity in bone. In an experiment designed to investigate whether callus could be produced by electrical stimulation, a direct current of 1 μ A was applied continuously for 3 wk to Vitallium electrodes that were inserted through the cortex into the medullary canal of a rabbit femur. At the end of the 3-wk period, a ridge of callus was observed, which ran between the electrodes both inside and outside the periosteum. There was more newly-formed bone on the inside of the periosteum in the region of the negative electrode than in the region of the positive electrode. The fact that less bone was formed at the positive electrode is an important finding in that it links together the electronegative property of bone under a mechanical stimulus with the formation of bone at the negative electrode during external electrical stimulation.

- 5275 THE INFLUENCE OF ELECTRIC POTENTIALS ON
PLATED BONES. (Eng.) Weigert, M. (Dept.
Orthopaedics and Traumatology, Urban Hosp., Berlin,
W. Germany); Werhahn, C. *Clin Orthop* (124): 20-30;
1977. (39 refs)

Experiments investigating the effect of electric potentials on plated bones are reported. Each of 27 rabbits treated with bilateral tibial osteotomy and compression plates received 3-15 μ A of constant direct current to one tibia for 21 days. The breaking strengths of the electrically-stimulated tibiae were higher in 19 animals (70.4%), the same in two animals, and lower in six animals when compared with unstimulated tibiae. The mean value of the additional maximum stress required to break the stimulated tibiae was 0.73 kg. When 15 other rabbits were similarly treated, with electrical stimulation applied to only one tibia in each animal, there was an increase in endosteal and periosteal callus formation and greater vascularization of the callus (on microangiography) in the stimulated tibiae as compared with nonstimulated tibiae. The fissure gap at the osteotomy site was smaller in stimulated tibiae compared with unstimulated tibiae, and bone in the fissure was of the mature lamellar type only in stimulated tibiae. Uptake of fluorochromes was greater in stimulated than in unstimulated tibiae. When both tibiae in each of five rabbits were doubly fixed with compression plates and a simulated piezoelectric potential (15 mV, 5-8 μ A, 0.33 Hz) was

applied to one tibia of each animal for periods ranging from 136-156 days, stimulated tibiae in three of five animals showed a 20% higher calcium and phosphate content of the stress-protected cortex as well as in increased uptake of fluorochromes in comparison with unstimulated tibiae.

- 5276 ELECTRICAL STIMULATION OF OSTEOGENESIS IN PERIODONTAL DEFECTS. (Eng.) Jacobs, J. D. (Dept. Orthodontics, Baylor Coll. Dentistry, Dallas, TX 75246); Norton, L. A. *Clin Orthop* (124): 41-52; 1977. (17 refs)

The effect of artificially-produced direct negative current on osteogenesis in pathologic defects found in the periodontium of dogs was investigated. Galvanic or thermocouple generators designed to deliver a current in the nanoampere range were implanted submucoperiosteally in the area of periodontal osseous defects in five dogs, with the negative electrodes extending into the osseous defects. The galvanic unit produced a constant direct current of 3-6 nA, while the thermocouple generator produced an oscillating direct current of approximately 0-20 nA. Clinical and radiographic evaluation revealed no significant changes in the depth of the defects. When the animals were sacrificed after 45 days of treatment, histologic measurements suggested that endosteal apposition was enhanced in all experimental sites in comparison with controls. Clinically, no gross adverse tissue reactions were observed during the experiment or at surgical re-entry. Further investigation is needed to determine the magnitude of current that best enhances osteogenesis in pathologic defects of alveolar bone.

- 5277 ELECTRICAL CALLUS AND CALLUS FORMATION BY ELECTRET. (Eng.) Yasuda, I. (Dept. Orthopedic Surgery, Kyoto Second Red Cross Hosp., Kamikyo-ku, Kyoto, Japan). *Clin Orthop* (124): 53-56; 1977. (10 refs)

In vitro and in vivo experiments dealing with electrically-induced callus formation are reported. When Vitallium electrodes were inserted through drill holes into the femur of a rabbit and were connected to a 1.5-V battery in series with a 1 megohm resistor, a continuous current of 1 μ A or less over a period of 3 wk produced a ridge of callus between the electrodes, which ran subperiosteally along the cortex and endosteally along the medullary canal. The amount of callus increased as the electrical current was increased and was significantly greater at the cathode than at the anode. As the current was increased from 1 μ A to 100 μ A, the quality of callus changed from osseous to cartilaginous or fibrous. When stainless steel electrodes were wound around the rabbit femur, a well-shaped callus formed between the electrodes when a current of 1 μ A was applied over a 3-wk period. When the cathode was wound around the femur and the anode was placed in muscle, the callus began at the cathode and grew toward the anode in an arc-like manner. In vitro experiments in which excised rabbit or human bone fragments in normal saline solution were

subjected to a current of 1 μ A also resulted in callus formation, which was similar in quality but less in quantity than that observed during in vivo experiments. When electret film was either simply laid on the femur of rabbits or was wrapped around the femur, the amount of callus formed was greater in the latter case than in the former. The amount of callus reached a maximum after 2 wk in the former case, with the callus gradually decreasing and becoming transformed into hard body tissue thereafter. When the electret film was wrapped around the femur, callus formation was especially noted on the flexor side of the femur, and the shape of the callus formed around the electret resembled a bridge above the electret. The bridge-like callus was bony hard after 4 wk.

- 5278 THRESHOLD LIMIT VALUES FOR CHEMICAL SUBSTANCES AND PHYSICAL AGENTS IN THE WORKROOM ENVIRONMENT WITH INTENDED CHANGES FOR 1976. (Eng.) American Conference Governmental Industrial Hygienists (P.O. Box 1937, Cincinnati, OH 45201). *Med Bull* 36(2/3): 135-202; 1977. (0 refs)

Threshold limit values for occupational exposure to chemical substances and physical agents are presented. The threshold limit value for occupational microwave exposure (100 MHz-100 GHz) where power densities are known and exposure time is controlled is as follows: for average power density levels up to but not exceeding 10 mW/cm², total exposure time shall be limited to the 8-hr workday (continuous exposure); for average power density levels ranging from 10 mW/cm² up to but not exceeding 25 mW/cm², total exposure time shall be limited to no more than 10 min for any 60-min period during an 8-hr workday (intermittent exposure); for average power density levels in excess of 25 mW/cm², exposure is not permissible. These threshold limit values represent conditions under which it is believed that nearly all workers may be repeatedly exposed without adverse effect. These values should be used as guides in the control of exposure to microwaves and should not be regarded as a fine line between safe and dangerous levels. For repetitively pulsed sources, the average power density may be calculated by multiplying the peak power density by the duty cycle (pulse duration in seconds multiplied by the pulse repetition rate in hertz).

- 5279 PHYSICAL PROPERTIES OF BIOLOGICALLY ACTIVE LOW-FREQUENCY ELECTROMAGNETIC FIELDS. (Ger.) Pfitzner, H. (Institut für Grundlagen und Theorie der Elektrotechnik, Technische Universität Wien, A-1040 Vienna, Gusshausstrasse 21, Austria). *Elektrotechnik und Maschinenbau* 94(7): 281-286; 1977. (20 refs)

A systematic review of 250 studies on the biologic effects of fields with a maximum frequency of 1 MHz shows an abundance of data on the effects of static electric and magnetic fields, in contrast to the smaller number of studies devoted to alternating magnetic and electromagnetic fields. Static electrical fields with potentials of up to 500 V/m

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are believed to have no biologic effect. A functional relationship is found between field intensity and frequency of alternating electric fields in relation to their biologic effect. A hypothetical curve showing the lowest effective field potential as a function of frequency is presented with the minimum biologic effect seen in the frequency range of 3-10 Hz. The effects of magnetic fields have been studied mainly for intensities that are not typical for either the natural or technical environments. The effect and its tendency are not proportional to the field intensity.

- 5280 TREATMENT OF NONUNION WITH CONSTANT DIRECT CURRENT. (Eng.) Brighton, C. T. (Dept. Orthopaedic Surgery, Univ. Pennsylvania Sch. Medicine, Philadelphia, PA); Friedenber, Z. B.; Mitchell, E. I.; Booth, R. E. *Clin Orthop* (124): 106-123; 1977. (44 refs)

The use of a constant direct current (10-20 μ A) for the treatment of nonunions in 57 patients (37 males and 20 females; average age, 37.3 yr) is reported. The average duration of nonunion was 3.3 yr. Cathodes were either drilled obliquely through one cortex until they came to rest in the nonunion site, or they were inserted directly into the nonunion site without passing through the cortex. The anode was attached to the skin with adhesive tape. The current was applied continuously for periods ranging from 9-12 wk. While a current of 10 μ A per cathode, which was used to treat the first 16 patients, proved sufficient to heal small bones such as medial malleoli, it was not adequate for larger bones. Thereafter, a current of 20 μ A/cathode was used. Also, the number of cathodes inserted into each nonunion site was increased so that two to four were used in each nonunion. Of the 57 patients treated with electricity, 39 (68.4%) achieved solid bony union, and 35 patients (61.4%) were healed on the first trial. Of 46 patients who were treated adequately with electricity, 39 (84.8%) achieved solid bony union, and the percentage of patients who went on to union on the first trial of electrical treatment was 76.1%.

- 5281 ELECTRET INDUCED CALLUS FORMATION IN THE RAT. (Eng.) Inoue, S. (Dept. Orthopedic Surgery, Gifu Coll. Dentistry, Murakami Memorial Hosp., 1-6 Wakamiya-cho, Gifu, Japan, 500); Ohashi, T.; Yasuda, I.; Fukada, E. *Clin Orthop* (124): 57-58; 1977. (7 refs)

Electret-induced callus formation in the rat is reported. A 7-mm wide Teflon film strip of electret (material with a permanent electrical polarization) was wrapped around the intact mid-femoral shaft of the right femur in 10 Japanese white rats. The mid-femoral shafts of the opposite femora were wrapped with regular (non-charged) Teflon film strips to serve as controls. After 3 wk, 9 out of 10 animals showed callus formation on the electret side. None of the animals showed callus formation on the control side. In 6 out of 10 of the animals, the callus

was wedge-shaped with the apex of the wedge pointing proximally on the flexor surface of the femur and extending proximally over the electret film. Histologic examination of the callus on the femur disclosed that the tip of the wedge-shaped bony callus was covered with thick fibrous connective tissue and young hypertrophic fibrous tissue. The callus itself consisted of cancellous bone. In some animals the new bone was covered only with a thin layer of fibrous tissue, but the bony callus itself contained normal-appearing marrow next to the original femoral cortex. This model of electret-induced callus formation should lend itself to the histo-biochemical study of electrically-induced osteogenesis.

- 5282 SURVIVAL OF CANINE KIDNEYS AFTER TREATMENT WITH DIMETHYLSULFOXIDE, FREEZING AT -80°C , AND THAWING BY MICROWAVE ILLUMINATION. (Eng.) Guttman, F. M. (Lady Davis Inst.-Jewish General Hosp., 5750 Cote des Neiges, Montreal, H3T 1E2, Canada); Lizin, J.; Robitaille, P.; Blanchard, H.; Turgeon-Knaack, C. *Cryobiology* 14(5): 559-567; 1977. (36 refs)

The survival of canine kidneys after treatment with dimethylsulfoxide (DMSO), freezing, and microwave thawing was studied. Kidneys removed from adult mongrel dogs were perfused with Perfudex plus DMSO (1.4 molar), modified Collins' solution with DMSO (1.4 molar), or modified Sacks' solution with DMSO (1.4 molar). Control kidneys were reimplanted in the groin with an end-to-end arterial anastomosis, an end-to-side venous anastomosis, and a tunneling uretero-vesical anastomosis. Control kidneys showed little toxicity and life-sustaining conservation. Experimental kidneys were frozen for 15 min to -80°C and were then thawed to 0°C over a period of about 90 sec in a 2,450 MHz microwave oven with a power output of 1.35 kW. The kidney was then autografted into the groin of the donor dog in a standard manner. Among 16 experimental dogs, eight survived for prolonged periods (12-14 mo) on a single frozen-thawed kidney for an overall success rate of 50%. In contrast, when conduction thawing in a saline bath was attempted only 1 of 13 kidneys survived.

- 5283 MONITORING AND DIAGNOSIS OF PULMONARY EDEMA BY MICROWAVES: A PRELIMINARY REPORT. (Eng.) Bragg, D. G. (Dept. Radiology, Univ. Utah Medical Center, Salt Lake City, UT 84132); Durney, C. H.; Johnson, C. C.; Pedersen, P. C. *Invest Radiol* 12(3): 289-291; 1977. (4 refs)

Initial studies using microwave energy for the monitoring of early pulmonary edema are reported. The experiments were performed on two anesthetized dogs monitored before and during artificially induced pulmonary edema. Microwave frequencies varying from 300-950 MHz were used, with most measurements utilizing 915-MHz microwaves. The microwave monitoring system consisted of a microwave generator, a directional coupler, a network analyzer, and a microwave antenna or applicator. The incident power

density produced by the applicator in free space at 915 MHz was less than $10 \mu\text{W}/\text{cm}^2$ (more than 1,000 times lower than the applicable safety standard). Excellent correlation was obtained between changes in microwave reflection and pulmonary physiologic indicators of developing pulmonary edema. In particular, the amplitude changes in the microwave signal directly paralleled the plotted curve of increasing left atrial pressure and long preceded abnormalities observed on serial chest radiographs and auscultatory findings.

- 5284 DISINFECTING EFFECT OF PULSED ELECTRICAL DISCHARGES ON BINARY BACTERIAL SUSPENSION. (Rus.) Zhuk, E. G. (No affiliation given). *Zh Mikrobiol Immunobiol* (7): 150-151; 1977. (0)

The disinfecting effect of pulsed electrical discharges (energy dose 2,650 J) on aqueous suspensions of *Escherichia coli* (5,000 cells/ml), STI anthrax vaccine spores (5,000 cells/ml), and their binary mixture was studied. Bactericidal effect was achieved with 14.5-22.1 impulses in the single cultures and with 20.2-23.8 impulses in the binary suspension. Sporocidal effect was achieved with 37.7-57.7 impulses in single culture and with 40.4-62.4 impulses in binary suspensions. Lethal energy doses were 3.8×10^3 erg for *E. coli* and 14.4×10^3 erg for anthrax bacillus spores in single suspensions. For the binary suspension containing the same numbers of cells, the lethal dose was 6.4×10^3 erg, regardless of species. The findings indicate that *E. coli* reduces the survival of STI spores and increases the efficiency of the pulsed discharges in binary suspensions due to the increased total cell surface.

- 5285 FAILURE OF CHRONIC EXPOSURE TO NONTHERMAL FM RADIO WAVES TO MUTATE *DROSOPHILA*. (Eng.) Mittler, S. (Dept. Biological Sciences, Northern Illinois Univ., DeKalb, IL 60115). *J Heredity* 68(4): 257-258; 1977. (12 refs)

The possible mutagenic effects of frequency-modulated (FM) radio waves on *Drosophila* flies were investigated. Female flies heterozygous for Bar eye were isolated and tested for lethals, and nonlethal strains were placed in a radio transmitter building, which was 45 m away from the base of a 300-foot antenna fed by a 50,000-W FM transmitter operating at a frequency of 98.5 MHz. The flies were exposed to a field strength of 0.3 V/m for 4,020 hr over a 32-wk period. Lethals were determined by isolating a mated heterozygous Bar female that produced no Bar-eye males among the offspring from matings with at least 10 wild-type eye males. These lethals were retested by isolating at least six heterozygous Bar females from each of the suspected lethals; if, in the next generation, they all proved to be lethals, the original classification of a lethal was kept. There was no significant difference in percentage of lethals from stocks exposed to nonthermal FM radio wave radiation (0.853%) and the percentage of lethals among control flies (0.895%)

not exposed to FM radio waves. Chronic exposure to 0.3 V/m of 98.5-MHz FM radio waves does not appear to be mutagenic to *Drosophila*.

- 5286 MICROWAVE FIXATION OF FETAL SPECIMENS. (Eng.) Petrere, J. A. (Dept. Toxicology, Parke, Davis and Co., Ann Arbor, MI 48106); Schardein, J. L. *Stain Technol* 52(2): 113-114; 1977. (4 refs)

Microwave fixation of whole rat and rabbit fetal specimens is described. Rat or rabbit fetuses were killed painlessly, opened at the abdomen and at the back of the neck, and placed in 10% buffered neutral formalin in plastic boxes. Optimal fixation results were obtained when the boxes were irradiated in a microwave oven for 2.0-2.5 min in the case of rabbits and 2.5-3.0 min in the case of rats. Rat fetuses irradiated for at least 2.5 min had adequately fixed viscera and produced well-stained skeletal specimens. Irradiation for more than 3 min made the tissue brittle and caused it to disintegrate when macerated. Exposures for longer than 3 min in the case of rabbit fetuses were also unsatisfactory. Although the technique does not rival the speed of ethanol fixation, the condition of the viscera is superior and the skeleton much more flexible. Microwave fixation saves a week of time with rats and almost 2 wk with rabbits when compared with routine formalin fixation methods.

- 5287 INFLUENCE OF INJECTED PSYCHOACTIVE DRUGS ON CYCLIC AMP LEVELS IN MOUSE BRAIN AND LUNG FOLLOWING MICROWAVE IRRADIATION. (Eng.) Palmer, G. C. (Dept. Pharmacology, Univ. South Alabama, Coll. Medicine, Mobile, AL 36688); Jones, D. J.; Medina, M. A.; Stavinoha, W. B. *Neuropharmacology* 16: 435-443; 1977. (65 refs)

The actions of various classes of psychotropic drugs on the steady-state in vivo levels of adenosine cyclic 3',5'-monophosphate (cyclic AMP) in the cerebral cortex, diencephalon, and lung of male Swiss mice subsequently sacrificed by 500 msec of 2,450-MHz microwave radiation (6 kW) were investigated. Chlorpromazine, chlorpromazine sulfoxide, para-hydroxy-amphetamine, caffeine, papaverine, pargyline, and amitriptyline caused an increase in the cyclic AMP level in the cerebral cortex, while alpha-methyl para-tyrosine produced a decrease in cerebral cortex cyclic AMP, and reserpine elicited no change. In the diencephalon, cyclic AMP was elevated by reserpine, chlorpromazine, and caffeine and was depressed by alpha-methyl para-tyrosine and chlorpromazine sulfoxide; the remaining agents caused no change. The following agents raised cyclic AMP in pulmonary tissue: reserpine, alpha-methyl para-tyrosine, papaverine, chlorpromazine, chlorpromazine sulfoxide, and amitriptyline. The cyclic nucleotide content of the lung was reduced by amphetamine, para-hydroxy-amphetamine, pargyline, and D-lysergic acid diethylamide. These studies indicate that the microwave method of tissue inactivation is a useful tool for evaluating drug action with respect to the steady-state levels of metabolically labile compounds. The results also indicate that, in vivo, psychoactive drugs influence steady-state levels of cyclic AMP

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in a manner that can differ from their action in vitro and that the same drug does not affect the cyclic nucleotide levels in an identical manner in different regions within the brain or lung.

- 5288 A NON-OPERATIVE SALVAGE OF SURGICALLY-RESISTANT PSEUDARTHROSES AND NON-UNIONS BY PULSING ELECTROMAGNETIC FIELDS: A PRELIMINARY REPORT. (Eng.) Bassett, C. A. L. (Orthopaedic Res. Lab., Columbia Univ. Coll. Physicians and Surgeons, New York, NY 10032); Pilla, A. A.; Pawluk, R. J. *Clin Orthop* (124): 128-143; 1977. (91 refs)

The therapeutic use of extremely low frequency pulsed electromagnetic fields for the nonoperative salvage of surgically resistant pseudarthroses and nonunions is reported. The electromagnetic field was induced by a quasi-square wave generator, which powered an "O"-shaped treatment coil that was applied to the patient to produce a pulsing electromagnetic field at right angles to the long axis of the bone. The pulse was asymmetrical with a rapidly rising leading edge (less than 10^{-6} sec). The total pulse width was approximately 300 μ sec, and the duty cycle was approximately 5:1. The peak induced current density was about 10 μ A/cm² tissue. Among 29 patients (17 recommended for amputation after at least one surgical repair failure), the overall success rate, including patients treated with inadequate pulse characteristics and those who failed to follow the protocol, was over 70%. An analysis of 43 additional patients treated with pulsed electromagnetic fields revealed that most patients required two facing coils for maximum repair rate. With this change, the percentage of success increased to an overall rate of 85%. The described electromagnetic technique appears to be both safe and effective and can be applied with or without surgery on an out-patient basis.

- 5289 EFFECTS OF LOW-LEVEL MICROWAVE RADIATION ON GERMINATION AND GROWTH RATE IN CORN SEEDS. (Eng.) Bigu-Del-Blanco, J. (Anatomy Dept. Queen's Univ., Kingston, Ontario, Canada); Bristow, J. M.; Romero-Sierra, C. *Proc IEEE* 65(7): 1086-1088; 1977. (5 refs)

The effect of microwave radiation on the germination and growth rate of corn seeds (*Zea mays*) was investigated. Specimens were irradiated in an anechoic chamber for 22-24 hr with continuous wave 9-GHz microwave radiation at power density levels ranging from 10-30 mW/cm². Anechoic chamber temperature of 23 (\pm 1) C and humidity of 70% were kept constant. Gross differences were observed between irradiated and control seedlings at power density levels as low as 10 mW/cm². Irradiated specimens had a dried and wrinkled rugose texture and were totally arrested in growth. Control seedlings remained healthy. The growth differential continued for 1-2 wk but eventually disappeared. Since temperature increases of up to 4 C were observed when corn seedlings inside plastic bags were irradiated with power density levels of up to 30 mW/cm², nonirradiated seeds were

incubated at comparable temperatures to investigate the effect of temperature elevation on seed growth. No temperature effect was observed, and the incubated seeds remained healthy and germinated as well as control seeds. Measurements of moisture loss showed that irradiated seedlings lost about five times as much moisture as control seedlings during the treatment. It is concluded that the microwave-induced growth inhibition was probably due to a loss of turgor resulting from water loss since full turgor is necessary for the growth of plant cells.

- 5290 BIOLOGICAL EFFECTS OF MICROWAVES (BOOK REVIEW). (Eng.) Blackman, C. F. (Health Effects Res. Lab., U.S. Environmental Protection Agency, Research Triangle Park, NC). *Am Sci* 65(5): 636; 1977. (0 refs)

A review of *Biological Effects of Microwaves* is presented. The book is highly valuable as an introduction to the complexities of microwave bioeffects research and covers subjects ranging from the operation of radiation-generating equipment to the parameters affecting the penetration and interaction of radiation with living systems. The book also offers reviews and comparisons of Soviet, Polish, and American research philosophies and results. Areas of microwave research that require more work to confirm and extend preliminary results are identified and highlighted.

- 5291 RADIO-FREQUENCY ELECTROMAGNETIC RADIATION FROM PORTABLE AND MOBILE TELECOMMUNICATION TRANSMITTERS. (Eng.) Thiel, J. F. In: *Measurements for the Safe Use of Radiation. Proceedings of an NBS 75th Anniversary Symposium held at National Bureau of Standards, Gaithersburg, MD on March 1-4, 1976.* pp. 199-202; 1976. (7 refs)

Measurements made on commonly available mobile and portable telecommunications systems indicate that individuals may be exposed to levels of electromagnetic radiation comparable to the current radiation protection guide, if they are at distances of less than 1 m from the antenna. At distances of 50 cm or less from antennas whose input power is 100 W, power densities (electric field strength equivalent of free space) in excess of 1 mW/cm² can be found. As one approaches the loading coils on antennas shorter than one quarter wave length, power densities in excess of several hundred mW/cm² are found. A magnetic field intensity equivalent to a free space power density of 2.5 mW/cm² was found at approximately 5 cm from the base of an antenna on a 2-W walkie-talkie operating in the very high frequency-high band. With the apparent increase and authorization of the land mobile radio spectrum, which includes the 406-512 MHz and 806-960 MHz frequency band as well as numerous bands below 300 MHz, consideration should be given to the applicability and interpretation of the current radiation protection guide. There exists a need for measurement standards in order to appropriately evaluate personal exposure, both in terms of occupational

risk and general public health risks. Effects of electromagnetic radiation on safety systems and flammable and volatile materials need to be evaluated.

- 5292 NON-IONIZING ELECTROMAGNETIC RADIATION STANDARDIZATION. (Eng.) Baird, R. C.; Sanders, A. A. In: *Measurements for the Safe Use of Radiation. Proceedings of an NBS 75th Anniversary held at National Bureau of Standards, Gaithersburg, MD on March 1-4, 1976.* pp. 417-425; 1976. (15 refs)

Activities of NBS relating to the standardization of nonionizing electromagnetic radiation are reviewed. NBS has developed accurate measurement and calibration techniques, which will be fully implemented by August 1976 when a new anechoic (reflection-free) chamber will be completed. The chamber will be adequate for free space calibration down to about 500 MHz. A series of transverse electromagnetic mode transmission cells will be employed to extend the calibration capabilities down to very low frequencies. The NBS is also developing stable transfer standards suitable for measurement assurance programs (MAP), and a pilot MAP with uncertainties of about ± 0.5 dB ($\pm 12\%$) is anticipated during 1977. There is still a need for probes with better characteristics for use as transfer standards, and NBS is currently developing a three-axis dipole-diode probe. Existing probes can be used for interim MAP's, and the overall accuracy can be improved later as better transfer standards become available.

- 5293 INTERNAL EM FIELD AND ABSORBED POWER DENSITY IN HUMAN TORSOS INDUCED BY 1-500-MHz EM WAVES. (Eng.) Chen, K.-M. (Dept. Electrical Engineering and Systems Science, Michigan State Univ., East Lansing, MI 48824). *IEEE Trans Microwave Theory Techniques* 25(9): 746-756; 1977. (12 refs)

A tensor integral equation method is used to obtain numeric results on the internal electromagnetic (EM) field and absorbed power density inside a human torso induced by both vertically and horizontally polarized EM waves of frequencies ranging from 1-500 MHz. The induced fields inside the torso are dependent on the frequency and torso geometry with a hot spot occurring in the neck area. For the case of vertical polarization, the normalized maximum induced electric field in an adult torso 1.7 m in height reaches a sharp maximum and the relative absorption area attains a weak peak at around 80 MHz. This implies that a resonance occurs in a human torso when the torso height is about 0.453 times the free-space wavelength of the incident EM wave. For horizontal polarization, the induced electric field appears to have two local maxima at 170 and 230 MHz. The absorbed power for the horizontal polarization case tends to increase monotonically with the frequency first and remains constant for frequencies higher than 170 MHz. At frequencies below 100 MHz, the induced field in an

adult torso is stronger for the vertical polarization case than for the horizontal polarization case; however, the opposite is true for frequencies above 170 MHz. The theoretic results on induced fields inside a typical adult torso were compared with published experimental results, and good qualitative agreement was found.

- 5294 METHODS FOR THE EVALUATION AND CALIBRATION OF MICROWAVE SURVEY INSTRUMENTS. (Eng.) Swicord, M. L.; Bassen, H. L.; Herman, W. A. In: *Measurements for the Safe Use of Radiation. Proceedings of an NBS 75th Anniversary Symposium held at National Bureau of Standards, Gaithersburg, MD on March 1-4, 1976.* pp. 99-105; 1976. (2 refs)

Facilities operated by the BRH of the FDA for the evaluation and calibration of microwave survey instruments are described. The facilities include an anechoic chamber with a precisely positionable cart for measuring gain and chamber standing waves. The operable frequency range is 900 MHz to 10 GHz. A laser provides a means of aligning antennas. The absolute calibration of distance and microwave power are performed by the NBS. The radiated electric field strength is then established by BRH as a primary standard using precise antenna gain measurement methods. An instrument evaluation facility includes an absorber-lined temperature chamber, a probe/slot-source positioning system, and devices for measuring the polarization response, modulation response, and the linearity of the microwave survey instruments.

- 5295 FUNCTIONAL RELATIONSHIP OF THE ATMOSPHERIC SPECTRUM OF ELECTRICAL DISCHARGES AND THE BIOLOGICAL ACTIVITY OF LIVING ORGANISMS. (Rus.) Zhgenti, T. G. (Tbilisi State Univ., Tbilisi, USSR); Kevanishvili, G. Sh. *Sobremennyye Akad Nauk Gruz SSR* 86(3): 617-620; 1977. (10 refs)

Calculations with respect to the spherical cell model have demonstrated that the low-frequency component of natural electromagnetic waves, when passing through living organisms are transformed into elastic vibrational energy of the membrane structure. This low-frequency electromagnetic radiation is present everywhere on earth and constitutes a direct source of mechanical energy. Such energy transfer is a necessary condition of life on Earth.

- 5296 CLINICAL EXPERIENCES WITH LOW INTENSITY DIRECT CURRENT STIMULATION OF BONE GROWTH. (Eng.) Becker, R. O. (Veterans Admin. Hosp., Syracuse, NY); Spadaro, J. A.; Marino, A. A. *Clin Orthop* (124): 75-83; 1977. (24 refs)

Over a 3-yr-period, the use of low intensity direct current stimulation of bone growth in 13 patients with a variety of non-unions and pseudarthroses is reported. In all, 17 attempts to stimulate bone

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growth in 13 patients were made and included five non-unions of long bones that were non-infected, five infected long bone non-unions, and seven non-unions of joint fusions or synostosis that were not infected. Direct currents ranging from 100-200 nA/cm were applied via a pure silver wire cathode inserted directly into the non-union site and a carbon anode applied to the skin surface. Overall, 10 out of 17 attempts to stimulate bone growth were successful; on a patient basis, the success rate was 9 out of 13. Preliminary data indicate that a range of total energy from 0.6-2.5 J is maximally effective.

- 5297 PRELIMINARY CLINICAL EVALUATION OF THE EFFECT OF SMALL ELECTRICAL CURRENTS ON THE HEALING OF JAW FRACTURES. (Eng.) Masureik, C. (Dept. Maxillo, Facial and Oral Surgery, Sch. Dentistry, Univ. Pretoria, Pretoria, South Africa); Eriksson, C. *Clin Orthop* (124): 84-91; 1977. (5 refs)

A clinical investigation was conducted to evaluate the effect of small electrical currents on the healing of mandibular fractures. A group of 40 control patients were treated by the normal technique of closed reduction, while another group of 40 patients were treated with electricity in addition to closed reduction. A direct current of 10 or 20 μ A was delivered through a platinum electrode to the jaw fracture site (negative electrode). The positive pole of the constant direct current generator was joined to an aluminum or copper plate, which was placed on the anterior chest of the patient to complete the circuit. The electrode was left in position for a period of 10-14 days. Out of 40 patients receiving electrical stimulation, 36 had a mobility after 2 wk that ranged from good to excellent; whereas, out of 40 control patients, 35 had poor to fair mobility after 2 wk. At 6 wk after reduction, there appeared to be little difference in mobility between controls and patients receiving electrical stimulation. Serum phosphatase and calcium were regularly measured in both groups. In electrically-stimulated patients, a decrease in serum phosphatase with time was associated with an increased healing rate.

- 5298 THE ELECTRICAL INDUCTION OF CALLUS FORMATION AND EXTERNAL SKELETAL FIXATION USING METHYL METHACRYLATE FOR DELAYED UNION OF OPEN TIBIAL FRACTURE WITH SEGMENTAL LOSS. (Eng.) Inoue, S. (Dept. Orthopedic Surgery, Gifu Coll. Dentistry, Murakami Memorial Hosp., 1-6 Wakamiya-cho, Gifu, Japan, 500); Ohashi, T.; Imai, R.; Ichida, M.; Yasuda, I. *Clin Orthop* (124): 92-96; 1977. (10 refs)

A case of a 44-yr-old man with delayed union of an open tibial fracture with segmental loss is presented in which electricity was applied to the bone defect through two screws that were connected to a methyl methacrylate skeletal fixation device. The screw closest to the fracture site was the cathode, and the

other was the anode. Originally, the patient had undergone iliac bone grafting in the defect of the tibia. However, gradual resorption of the bone graft occurred. Electrical stimulation was employed; a 1.5-V battery was used to apply 20 μ A of constant direct current to the tibia. The fracture developed electrically-induced callus formation around the cathode. Callus extended to the anode, and solid bony union ensued. The patient is presently walking without any external support.

- 5299 MODEL FOR SOME NONTHERMAL EFFECTS OF RADIO AND MICROWAVE FIELDS ON BIOLOGICAL MEMBRANES. (Eng.) Barnes, F. S. (Dept. Electrical Engineering, Univ. Colorado, Boulder, CO 80309); Hu, C-L. J. *IEEE Trans Microwave Theory Techniques* 25(9): 742-746; 1977. (18 refs)

A mathematic model of mechanisms by which nonthermal effects can occur in biologic materials exposed to microwave and radio frequency fields is presented. Both shifts in ion concentrations across a membrane and the orientation of long chain molecules are shown to be possible. Where a high pulsed field of 1 kV/cm in free space is incident on a high-water-content dielectric material with a membrane at a right angle to the field, ion currents of approximately 10^8 ions/sec are calculated. Since experiments on chemotaxis indicate that a few thousand molecules may be important in affecting the response of a white blood cell, it is not inconceivable that exposures at this level of the order of 10 μ sec could mean significant biologic changes in the performance of a cell. At a power level of 10 mW/cm² and at a field strength in a high-water dielectric medium enclosed membrane of 4.4 V/cm, an ion flow of approximately 400 ions/sec is calculated for a cell with a 10^{-6} -cm² surface area. Therefore, to obtain 500-1,000 molecules/cell would require an exposure of a few seconds. A model for the torques applied to long chain molecules oriented in biologic materials exposed to moderate electric fields is also presented.

- 5300 INVESTIGATIONS ON THE EFFECT OF AN ELECTROSTATIC FIELD FREE OF RESIDUAL WAVES ON THE MOTILITY OF THE MOUSE. (Ger.) Fischer, G. (Hygiene-Institut, Universität Graz, Universitätsplatz 4, A-8010 Graz, Austria). *Zentralbl Bakteriol [Orig B]* 164(5/6): 439-446; 1977. (8 refs)

The effects of electrostatic field with a residual wave component of 1% (field potential 4,500 V/m), of pure residual wave component (32 Vs/s, field strength 120 V/m/ss), and of electrostatic field free from residual waves (900 V, field strength 4,500 V/m), and of Faraday cage on the motility of 6-wk-old NMRI-Han female mice were studied in a 20-day experiment. After a 20-day adaptation period, the motility was measured by means of electric eyes in the cages, whose beams were interrupted by the moving animals. Compared with the motility measured in the Faraday cage, the motility measured in the pure electrostatic field without residual waves

was only insignificantly higher, while electrostatic field with the residual waves and pure residual wave component caused a significant increase in motility. There was no significant difference in motility between animals kept in electrostatic field without residual wave component and in those exposed to the residual wave component only. The findings suggest that the stimulating effects attributed to the electrostatic field are due to the residual wave component.

5301 LABILE INTERMEDIARY METABOLITES IN RAT BRAIN DETERMINED AFTER TISSUE INACTIVATION WITH MICROWAVE IRRADIATION. (Eng.) Medina, M. A. (Dept. Pharmacology, Univ. Texas Health Science Center at San Antonio, San Antonio, TX 78284). *Brain Res* 132(1): 149-152; 1977. (13 refs)

Labile intermediary metabolites in the brain were determined after exposure of male Sprague-Dawley rats to 6 kW (5.5 kW of power to the rat head) microwave radiation for a 0.6-sec period, which ensured adequate inactivation of brain tissue. A comparison of different metabolite levels in the whole brain after microwave irradiation with those reported after use of a freeze-blowing method revealed adenosine triphosphate, adenosine diphosphate, adenosine monophosphate, phosphocreatine, pyruvate, and lactate levels of 2.80 ± 0.05 , 0.352 ± 0.024 , 0.052 ± 0.005 , 3.37 ± 0.16 , 0.121 ± 0.012 , and 1.26 ± 0.08 $\mu\text{mol/g}$ wet weight, respectively, after microwave irradiation as compared with corresponding levels of 2.45 ± 0.05 , 0.561 ± 0.022 , 0.041 ± 0.001 , 4.05 ± 0.07 , 0.091 ± 0.001 , and 1.23 ± 0.07 $\mu\text{mol/g}$, respectively, after freeze-blowing. With the exception of the lactate values, all of the other metabolite concentrations in the microwave-treated group were significantly different from those of the freeze-blown group. However, the pattern of differences was not that which would be observed under anoxic conditions as a result of incomplete enzyme inactivation by microwave irradiation. The differences are probably due to the analytical techniques employed in the different laboratories. The concentrations of metabolites in the deeper brain areas (cerebellum, medulla-pons, midbrain) were not significantly different from those observed in the more superficial cerebrum after microwave irradiation with the exception of the adenosine diphosphate value (0.515 ± 0.027 $\mu\text{mol/g}$) for the midbrain versus that for the cerebrum (0.360 ± 0.035 $\mu\text{mol/g}$). Uniform inactivation allows more valid comparison of regional substrate levels and any alteration produced by drugs or chemicals.

5302 NEUROPHYSIOLOGICAL ESTIMATES OF HUMAN PERFORMANCE CAPABILITIES IN AEROSPACE SYSTEMS. (Eng.) Adey, W. R. (Univ. California, Brain Res. Inst., Los Angeles, CA 90024). 143 pp.; 1976. [available through National Technical Information Services, Springfield, VA 22161, Document No. AD A038208]. (112 refs)

The effects of weak low frequency electric fields

on calcium efflux from isolated chick and cat brain were studied as part of a project to determine neurophysiologic estimates of human performance capabilities in aerospace systems. Freshly isolated chick cerebral hemispheres were equilibrated with a calcium Ringer's solution containing radiolabeled calcium ion for 30 min. Washed tissue portions were then exposed to sinusoidal electric fields at either 1, 6, 16, or 32 Hz with electric gradients of 5, 10, or 56 V/m in air for each frequency over a 20-min period. Calcium efflux was then measured in 0.2 ml of supernatant and compared with efflux from unexposed control samples. A frequency sensitive tuning curve showed a sharply reduced efflux of 15-20% at 6 Hz and 16 Hz. Similar but smaller reductions occurred at 56 V/m. The threshold gradient was around 10 V/m, but insignificant trends occurred at 5 V/m. No effects were seen at 100 V/m. There are thus both frequency and amplitude windows for this effect. Cat visual, auditory, suprasylvian, and sensorimotor cortex tested at 1, 6, 16, 32, and 75 Hz also showed significantly decreased effluxes at 6 Hz and 16 Hz; nonsignificant trends were observed at all other frequencies. At 10 V/m, nonsignificant trends occurred at frequencies of 6 and 16 Hz. Oscillating extremely low frequency fields at 6-32 Hz reduce calcium efflux; whereas, it was previously shown that weak very high frequency fields, which are amplitude modulated at the same frequencies, increase efflux. Both effects can be explained by an excitation model in cerebral neurons, with longitudinal calcium binding to membrane surface macromolecules being the initial step before classic secondary transmembrane events. Initial steps in calcium binding and release would involve cooperative interactions with fixed charges on surface polyanions. Intrinsic electroencephalogram signals are sufficient to elicit these effects and may relate to a second signaling system.

5303 HUMORAL IMMUNITY OF JAPANESE QUAIL SUBJECTED TO MICROWAVE RADIATION DURING EMBRYOGENY. (Eng.) Hamrick, P. E. (Natl. Inst. Environmental Health Sciences, P.O. Box 12233, Research Triangle Park, NC 27709); McRee, D. I.; Thaxton, P.; Parkhurst, C. R. *Health Phys* 33(1): 23-33; 1977. (39 refs)

Fertile Japanese quail (*Coturnix coturnix japonica*) eggs were exposed to continuous wave microwave radiation at an intensity of 50 W/m^2 and a frequency of 2,450 MHz. The calculated absorbed power density was 4.03 W/kg. The eggs were exposed throughout the first 12 days of the normal 17.5-day incubation period. After hatching, exposed and control quail were reared in the conventional laboratory manner. The weights of the exposed males at the ages of 4 and 5 wk were 12 and 7%, respectively, less than those of control males. These differences approached statistical significance ($p < 0.05$). At 5 wk of age, the quail were challenged with sheep red blood cells (SRBC) and the levels of anti-SRBC antibodies were determined. The levels of specific anti-SRBC antibodies, determined 4 days after antigen challenge, were of the same magnitude for both exposed and control quail. Following this assessment of humoral

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immunity, the quail were sacrificed and the bursa and spleen were removed for weight comparisons with controls. The weights were not altered significantly by the microwave exposure. The findings indicate that embryonic exposure under the above conditions did not impair the development of humoral immunity in juvenile quail.

- 5304 LIGHTNING-STRIKE DISASTER AMONG CHILDREN. (Eng.) Myers, G. J. (Dept. Pediatrics, Univ. Rochester Sch. Medicine and Dentistry, 601 Elmwood Ave., Rochester, NY 14642); Colgan, M. T.; VanDyke, D. H. *JAMA* 238(10): 1045-1046; 1977. (7 refs)

A lightning strike involving 47 children and counselors (ages, 3-21 yr) is described. The children had taken shelter under some trees; they were dressed in wet bathing suits or light clothing and were either barefooted or wearing sandals. A lightning bolt struck the trees, knocking 16 children to the ground. Four children required hospital admission. A 14-yr-old girl, who was standing next to a tree, suffered immediate cardiorespiratory arrest. On the third hospital day, her electroencephalogram was silent, and she died on the seventh hospital day. Autopsy revealed extensive brain softening, pulmonary edema, bronchopneumonia, a large diaphragmatic myocardial infarction, and acute fatty liver changes. A 7-yr-old girl who was rendered unconscious developed subsequent seizures and fixed postures of hyperextended arms, flexed wrists, tightly clenched hands, and rigidly extended legs. There has been little neurologic improvement and no apparent recognition of her surroundings 20 mo after the accident. A 15-yr-old girl, who showed flaccid paralysis of both legs and absent reflexes on initial examination, had recurrent fear reactions for several days. Her paraparesis slowly improved, and she now walks in braces. The fourth admitted victim was a 10-yr-old boy with a small second-degree burn over his left groin and a larger first-degree burn over the right chest and abdomen. Injury from lightning may result from direct strike, side flash where the current discharges from a vertical object through the air to a nearby vertical object, or stride potential where a person standing near the point of lightning strike develops a potential difference between the legs. Immediate cardiorespiratory resuscitation of the lightning victim is the most important aspect of management. Regarding prevention, a person caught in the open with no shelter available should curl on the ground on his side with his hands close together to reduce contact points or he should squat with his feet together.

- 5305 EFFECTS OF NON-IONIZING RADIATION GIVEN PRIORITY STATUS BY CONGRESS. (Eng.) Harris, P. (Affiliation not given). *Microwaves* 16(8): 9-10; 1977. (0 refs)

The National Academy of Sciences is expected to be given a mandate by Congress during the fall of 1977 to conduct a comprehensive study of the current

state of knowledge on the health effects of non-ionizing radiation. Included in this study will be an evaluation of current radiation standards and a look at likely hazards of emerging technologies. The Academy is also developing a proposal to study the impact on over-the-air communications systems and on other microwave utilizing systems that would result from taking regulatory action on nonionizing radiation. A criteria document for occupational exposure to radiofrequency and microwave radiation is being planned by NIOSH; the agency is also updating an extensive bibliography of world literature on the subject. One concern of NIOSH is the possibility of cancer induction by Tacan systems. A Tacan repairman, who had been diagnosed as having carcinoma of the pancreas, recently filed for workman's compensation. An Army microwave research program is being conducted that includes investigations of frequency-dependent energy absorption in physical models, animals, and in organ-specific experiments. The Navy is conducting a probe of microwave and extremely low frequency radiation in support of its Project Seafarer Communications System. At congressional hearings, such agencies produced a consistent pattern of testimony indicating that research into nonionizing radiation is in its infancy compared with ionizing radiation research.

- 5306 ELEVATION IN RAT BRAIN HISTAMINE CONTENT AFTER FOCUSED MICROWAVE IRRADIATION. (Eng.) Hough, L. B. (Dept. Pharmacology, Univ. Michigan, Ann Arbor, MI 48109); Domino, E. F. *J Neurochem* 29(2): 199-204; 1977. (21 refs)

Male albino Holtzman rats were maintained in 12-hr light-dark cycles and were either decapitated at room temperature or subjected to microwave irradiation (1.3 kW) followed by decapitation 2-4 hr into the light cycle. The microwave radiation was focused and pulsed on the rat's head so that the rats were killed by 3-6 sec of microwave heating (brain temperature, 70-80 C). Rat brain histamine content after microwave irradiation nearly tripled in comparison with decapitated controls (124 ± 5 versus 42 ± 8 ng/g). Histamine assays at various times after decapitation revealed that histamine levels were not changed up to 30 min after decapitation and were reduced by 50% after 60 min. If brain histamine values found after decapitation represent the remainder of a rapidly depleting metabolic pool, then microwave treatment of rat brain after decapitation should not elevate the histamine content. However, the histamine content after such treatment was elevated, and histamine levels after microwave irradiation of isolated brain were indistinguishable from those in the brains of rats killed by microwave heating. If microwave treatment caused a redistribution of histamine from pellet to supernatant, the pellet produced by heating and centrifuging brain homogenates from decapitated rats should contain histamine in sufficient quantity to account for the microwave-decapitation discrepancy. However, pellets had less than 7 ng/g histamine, whether from decapitated or microwave-treated animals. Microwave irradiation did not enhance the formation of histamine after intraventricular histi-

dine administration, indicating a lack of microwave-induced histidine decarboxylation. Although the elevation in rat brain histamine after focused microwave irradiation is probably not artifactual, the mechanism responsible for this phenomenon remains obscure.

- 5307 MICROWAVE THERMOGRAPHY. (Eng.) Cronin, M. P. (No affiliation given). *Appl Radiol* 6(3): 139-140, 158-159. (0 refs)

The value of microwave thermography in detecting breast cancer was studied. Nearly 2,000 patients were examined with this method at Faulkner Hospital, Boston, over a period of 1.5 yr. A total of 26 cancers were found by microwave thermography and confirmed by biopsy. The true-positive rate of conventional infrared thermographic technique was 77%, while the true-negative rate was 68%. With microwave thermography the results were almost identical in terms of percentages, but the cases detected by the two techniques were different. When infrared and microwave thermography were combined, the detection rate rose to 96%. The basic difference between the two techniques is that microwave detectors can see down to a depth of 10 cm, as compared with only 10 μ m with infrared detectors. The microwave receivers are capable of detecting temperature changes of about one-tenth of one degree. With xeromammography, the true-positive rate is 89% and the true-negative rate is 92%. However, neither thermographic method has yet been shown capable of detecting early cases of cancer.

- 5308 RELATIONSHIP BETWEEN THE FREQUENCY OF HYPERTONIC CRISES AND CHANGES OF THE SOLAR ACTIVITY AND THE EARTH'S MAGNETIC FIELD INTENSITY. (Rus.) Bardov, V. G. (A. A. Bogomolets Kiev Medical Inst., Kiev, USSR); Gabovich, R. D.; Nikberg, I. I. *Gig Sanit* (8): 111-115; 1977. (7 refs)

Correlations were studied between sunspot activity and related changes in the intensity of the earth's magnetic field and the frequency of hypertensive crises on the basis of 187,031 hypertensive crises recorded during the 1968-1973 period in the Kiev area. Diurnal distribution of the hypertensive crises was studied in 34,078 cases as a function of the astrophysical changes. No correlation was found between the sunspot activity and the frequency of hypertensive crises in data representing monthly and decade averages. However, significant correlation (a factor of about 0.2) was obtained for diurnal periods. Considerable increase was found in the frequency of hypertensive crises on days following chromospheric outbursts, which generate magnetic storms on the earth. Other parameters of solar activity showed no correlation with hypertensive reactions. Sharp increase was found in the incidence of hypertensive crises at the beginning of weak to moderate magnetic storms and on the eve of powerful to highly powerful storms, and this rise was followed by a decline. Sharp increase was seen in the frequency of hypertensive crises not only in

connection with magnetic storms but also with sudden disturbances and variations of the magnetic field intensity, i.e., increases or decreases of field intensity by over 60% of the intensity on the previous day. These findings are significant for the prophylaxis and treatment of hypertensive crises.

- 5309 HYPERTHERMIA BY LOCAL EM HEATING AND LOCAL CONDUCTIVITY CHANGE. (Eng.) Guru, B. S. (Engineering Div., Universal Electric Co, Owosso, MI); Chen, K.-M. *IEEE Trans Biomed Eng* 24(5): 473-477; 1977. (7 refs)

Theoretic calculations and experiments with saline models were performed to determine the effect of local electromagnetic (EM) heating and local conductivity change on the absorbed power in a local region of a biological body. When the frequency of the EM field was in the range of 1-100 MHz, an increase in the conductivity of the local region usually caused a decrease, instead of an increase, of the absorbed power in that local region. In the microwave frequency range, the absorbed power density in the local region increased initially and then decreased as the conductivity of the local region was continuously increased. This suggests the existence of an optimum conductivity for the most effective local EM heating. However, microwave radiation will not be effective if the local region is deep inside the body because of its shallow penetration depth.

- 5310 THE PATHOPHYSIOLOGY OF ACUTE ELECTRIC INJURIES. (Eng.) Hunt, J. L. (United States Army Inst. Surgical Res., Brooke Army Medical Center, Fort Sam Houston, TX); Mason, A. D.; Master-son, T. S.; Pruitt, B. A. *J Trauma* 16(5): 335-340; 1976. (5 refs)

Animal experiments on the pathophysiology of acute electrical injuries are reported. In a pilot study with adult mongrel dogs shocked with 60-Hz alternating currents at potentials ranging from 125-1,000 V, cutaneous injury was observed at each voltage, but deep muscle injury was minimal unless 500 V or more were used. Sprague-Dawley rats were shocked with 250 V by placing electrodes to the distal end of one fore and one hind paw. The shock was continued until the current arced. An inverse relationship was observed between voltage and the time of shock application necessary for current arcing. Amperage measurements during electric shock revealed a slow initial rise followed by a rapid elevation, which peaked and then precipitously fell to zero when the current arced. Regardless of the amount of voltage, the most extensive cutaneous and deep tissue injury occurred when the animal was shocked a sufficient length of time for the current to arc. The extent of tissue injury both beneath and adjacent to the contact site was directly proportional to the surface area of the electrode. The volume of tissue traversed by the electric current was more closely related to the extent of tissue injury than the

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internal resistance of the individual tissues. If the electrodes were in close enough proximity so that their spheres of heat injury overlapped, all interposed tissue in the extremity was coagulated, and the limb was mummified. The rate of tissue temperature rise paralleled the rate of increased amperage. The average preshock subcutaneous temperature was 37 C. When the shock was maintained long enough for the current to arc, tissue temperature adjacent to the contact site always exceeded 60 C. Arteriograms revealed that vascular occlusion occurred immediately at the time of injury, and there was no arteriographic evidence of delayed or progressive vascular occlusion. Although muscle injury occurred at the time of initial thermal insult, progressive or de novo muscle necrosis was not seen.

- 5311 CATARACTS AND AVIONIC RADIATIONS. (Eng.) Zaret, M. M. (Dept. Ophthalmology and Physiology, New York Univ. Sch. Medicine, New York, NY); Snyder, W. Z. *Br J Ophthalmol* 61(6): 380-384; 1977. (16 refs)

Nine cases of hertzian radiation-induced cataracts among personnel working in operational aviation environments, where they were irradiated repeatedly at subliminal nonthermal field intensities, are reported. The cases included three radar technicians, five air traffic controllers, and one airline pilot. The resultant ocular pathology evolved slowly over a period of years in a way similar to other forms of radiation injury. At the time of examination, all of the lesions had progressed to a relatively late state, exhibiting not only capsular cataract but also vesiculation and opacification of the proximal subcapsular lens substance. Histologic findings of scattered areas of degenerated lens fibers abnormally adherent to the internal edge of the capsule correlated with slit-lamp signs of honeycomb capsulopathy, the earliest clinically recognizable stage of hertzian radiation cataractogenesis.

- 5312 A STUDY OF THE EFFECT OF ELF ELECTROMAGNETIC FIELDS UPON *DROSOPHILA MELANOGASTER*. (Eng.) Bender, H. A. (*Drosophila* Res. Lab., Dept. Biology, Univ. Notre Dame, Notre Dame, IN). 18 pp.; 1976. [available through National Technical Information Services, Springfield, VA 22161, Document No. AD A035956]. (1 refs)

Drosophila melanogaster (fruit flies) were exposed to 20 V/m (root mean square) and 2 G (root mean square) at continuous wave frequencies of 45 and 75 Hz for a period of 48 hr as part of a confirmation study to determine biologic effects of extremely low frequency electromagnetic environments. The classical Muller-5 technique for the detection of sex-linked lethals was employed to study mutation rate. The sample size was sufficient to detect a moderate as well as a strong mutagenic effect of the fields tested. No indication of a mutagenic effect was found, suggesting that such weak ELF electromagnetic fields have no mutagenic effect at least within the

limits of the sensitivity of the Muller-5 technique. Sufficient dosages were not tested to demonstrate a dose-related effect.

- 5313 AN ECOLOGICAL SURVEY OF PLANTS EXPOSED TO ELF ELECTROMAGNETIC FIELDS. (Eng.) Rosenthal, G. M. (Biological Sciences Collegiate Div., Univ. Chicago, IL 60637). 42 pp.; 1976. [available through National Technical Information Services, Springfield, VA 22161, Document No. AD A035958]. (0 refs)

A survey of vegetation near the antennae at the Wisconsin Test Facility was made during the summer of 1971 as part of a program to determine possible biologic effects of extremely low frequency (ELF) electromagnetic environments similar to those envisaged in the vicinity of the Navy's proposed ELF communication system (Projects Sanguine and Seafarer). The antenna array at the facility includes a 14-mile long north-south antenna and a 14-mile long east-west antenna positioned so that they cross at their midpoints. Both antennae operate at a maximum current level of 300 A in the ELF range. Since July 1969, the test facility was operated on a 5-day week, 6 hr/day test schedule at a frequency of either 45 or 75 Hz. An analysis of the vegetation survey data collected in 1971 revealed a normal pattern of species composition, species distribution, and community structure. No indication of any effect from the ELF field was noted.

- 5314 EFFECT OF MAGNETIC FIELDS ON YEAST CELLS. (Ger.) Schaarschmidt, B. (FB Biologie, Institut für Biophysik (WE 01) der Freien Universität, 1000 Berlin 33, Habelschwerdter Allee 30, W. Germany). *Naturwiss Rundsch* 30(10): 365-366; 1977. (33 refs)

The effects of static magnetic field (maximum intensity 6,000 A/cm) on yeast cell cultures were studied. The lowest effective dose was about 4,000 A/cm. While there was no differences from the control in dry weight, the magnetic field caused a 12% reduction in the number of yeast cells, which had increased weight and volume. The magnetic field increased the aerobic metabolism by 20% and the anaerobic metabolism by 15%. No dose-effect relationship was established. Previous exposure to the magnetic field had no influence on the inactivation of the yeast cells by x-rays, but the reactivation rate was considerably higher than in the culture not exposed to the magnetic field. Exposure to the magnetic field following the x-ray exposure had no influence on reactivation.

- 5315 USE OF SUPER-HIGH FREQUENCY TO HEAT UP DEEP-FROZEN ERYTHROCYTES. (Rus.) Zaliubovskaia, N. P. (I. I. Mechnikov Kharkov Inst. Microbiology, Vaccines and Sera, Kharkov, USSR); Kiselev, R. I.; Deviatkov, N. D. *Probl Gematol Pereliv Krovi* 22(8): 56-57; 1977. (0 refs)

The biochemical effect of thawing deep-frozen erythrocytes by high-energy magnetron radiation (600 W, 2,400 MHz) was studied. The erythrocytes were deep-frozen in polyethylene oxide (molecular weight of 4,000) to -196°C at a rate of 40 $^{\circ}\text{C}/\text{sec}$ and were stored at -196°C for 0.5-24 hr before thawing. Erythrocytes deep-frozen in the same manner but thawed in water bath at 40 $^{\circ}\text{C}$ in 40-50 min were used for control. The high frequency thawing took 40-60 sec. After high-frequency thawing the free hemoglobin (Hb) level was 432 mg% vs. 340 mg% in the control, and the electrophoretic mobility was $1.17 \pm 0.003 \mu\text{sec}/\text{V}/\text{cm}$ vs. $1.21 \pm 0.002 \mu\text{sec}/\text{V}/\text{cm}$ in the control. There were no differences between the erythrocytes thawed by high-frequency radiation and the control in Hb fractions, adenosine triphosphate concentration, and glycolytic activity of the erythrocytes, nor in erythrocyte vitality. The findings indicate the suitability of this method for thawing deep-frozen erythrocytes; however, the field intensity should be increased to 800-1,000 W to minimize the thawing time.

- 5316 CURRENT PROBLEMS OF THE BIOLOGICAL EFFECT OF MICROWAVES. (Rum.) Vasilescu, C. (Laboratorul de biofizica, I.M.F., Bucharest, Romania); Zăciu, C. *Rev Ig [Pneumofiziol]* 26(1): 75-80; 1977. (17 refs)

Studies on the biological effects of microwaves are reviewed. While millimeter waves are absorbed by the superficial layers of the skin, the depth of penetration of centimeter waves is 2-4 cm, and that of decimeter waves is even more. Exposure to high-intensity microwave fields causes hyperthermia, which may be fatal to animals under certain circumstances. Exposure to low-intensity microwave radiation causes reversible morphologic and physiologic changes in experimental animals (cutaneous nerve fiber changes, fine structural changes in the brain cortex, manifesting in a depression of the conditioned reflexes and reduced sensitivity to auditory stimuli, and degenerative changes in the parenchymatous organs). Long-term exposure (more than 12 mo) may produce irreversible changes.

- 5317 PHYSIOLOGICAL AND BIOCHEMICAL PARAMETERS FOLLOWING TWO LONG-TERM EXPOSURES OF MICE TO MICROWAVE FIELDS (Meeting Abstract). (Ger.) Koessler, F. (No affiliation given); Lange, F.; Kupfer, J.; Rothe, R. *Z Gesamte Hyg* 23(4): 250; 1977. (0 refs)

The physiologic and biochemical effects of exposure to microwave fields (2 mW/cm², 6 hr/day, 9 or 12 wk) were studied in mice. The investigation of the spontaneous motor activity showed a training effect both in the control group and in the exposed group, but it was more pronounced in the latter. The hemoglobin levels showed a slight decline in the control, but they remained constant in the exposed groups. Exposure for 9 or 12 wk had no effect on the body weight, erythrocyte and leukocyte counts, blood

sugar level, differential blood picture, electrophoresis, total oxalate transaminase and creatine phosphokinase. The findings indicate that the exposure had no deleterious effect on physiologic and biochemical parameters.

- 5318 IMPROVING THE THERAPEUTIC EFFECT OF INDUCTOTHERAPY OF THE LUMBAR REGION IN DERMATOLOGY. (Rus.) Skripkin, Iu. K. (Dept. Dermatology and Venerology, N. I. Pirogov Second Moscow Medical Inst., Moscow, USSR); Borisenko, K. K.; Korotkii, N. G. *Sov Med* (7): 67-71; 1977. (17 refs)

The effectiveness of inductothermia (15.56 MHz, 150-200 μA , 10-20 min qod, 10-20 sessions) was studied in 48 patients with psoriasis and 32 patients with lichen planus. All patients received dopegit ($2 \times \frac{1}{2}$ tablets/day) starting on the day before the initiation of inductothermia, and 19 patients also received reserpine and raunatin (1-3 tablets/day). Clinical effect was observed usually after the first 3-5 sessions, manifesting in considerable alleviation of pruritus, of inflammation, and of neurotic symptoms, and in an improvement of the general condition of the patients. Clinical cure and considerable improvement was seen in 56 patients; improvement in 21. Inductothermia was suspended in three patients due to pyoderma.

- 5319 EFFECT OF ELECTRICAL STIMULATION OF THE BLADDER NERVE IN THE NEURON-CAPILLARY RELATION IN THE BLADDER GANGLION IN FROGS. (Rus.) Pastukhov, V. A. (Lab. Morphology of the Central Nervous System, I. P. Pavlov Inst. Physiology, USSR Acad. Sciences, Leningrad, USSR). *Fiziol Zh SSSR* 63(8): 1206-1209; 1977. (7 refs)

The effect of pulsed electrical stimulation (10 or 70 impulses/min, pulse time 0.5 msec, amplitude 10 V, length of stimulation 15 min) of the vesical nerve of *Rana temporaria* was studied, and the relationship between neurons and capillaries investigated. Both high-frequency and low-frequency stimulation caused significant increase of the capillary lumen after a temporary reduction. The diameter of the capillaries and the volume of the neuron increased in most cases, leading to an increased capillary-neuron contact surface or to the reduction of the distance between the capillaries and neurons. Shrinkage of the neuron and increase of the distance between neurons and capillaries were seen in some cases following high-frequency stimulation.

- 5320 ENERGY FLUX ALONG HIGH VOLTAGE TRANSMISSION LINES. (Eng.) Hart, F. X. (Dept. Physics, Univ. South, Sewanee, TN 37375); Marino, A. A. *IEEE Trans Biomed Eng* 24(5): 493-495; 1977. (2 refs)

A mathematic calculation of the ground level energy flux profile of a modern three-phase extremely high-

voltage overhead transmission is presented. The method of images was used to find the electric field of the conductor distribution as well as the magnetic field. A graphic analysis of the average Poynting vector as a function of distance from the center line for a proposed Pannell Road-Sterling-Volney 765-kV transmission line revealed that the extremely low frequency (ELF) energy flux does not decrease to the level of the United States microwave exposure standard (10 mW/cm^2) until about 108 m from the center line. The corresponding distance for the Soviet microwave exposure standard (0.1 mW/cm^2) is about 210 m. While the United States microwave standard is based exclusively on physiologic considerations involving tissue heating, the Soviet microwave protection level postulates other possible mechanisms. The extent to which such mechanisms are also operative at a frequency of 60 Hz and the existence of mechanisms peculiar to the ELF region are both presently undetermined.

- 5321 A REPORT ON THE PROBLEMS OF THE DANGERS INVOLVED IN THE AREA OF ELECTROMAGNETIC RADIATION. (Ger.) Potschkat, G. (Institut für Rundfunktechnik, Munich, W. Germany); Kienast, D. *Rundfunktechnische Mitteilungen* 21(3): 97-107; 1977. (13 refs)

Theoretic and model studies of the possible dangers of electromagnetic radiation in the vicinity of high-power transmitters are described. In electromagnetic fields, voltage can be induced between a conductive object and ground, as well as between sections of the conductor. Depending on the field intensity, the induced voltage can be high enough to cause skin burn and electric shock upon contact. Model tests simulating moving objects (motor vehicles) revealed that the induced voltage in the vehicle reaches 20 V at frequencies of up to 1 MHz and a reference field potential of 10 V/m. At similar reference field potentials, the maximal active power calculated was 675 mW for frequencies of 10 MHz and 57 mW for 1 MHz.

- 5322 INTRODUCTION. (Eng.) Sheppard, A. R.; Eisenbud, M. In: *Biological Effects of Electric and Magnetic Fields of Extremely Low Frequency*. (New York: New York Univ. Press): pp. (1) 1-7; 1977. (19 refs)

An introduction to a scientific literature review on the effects of electric and magnetic fields in the extremely low frequency range (0-300 Hz) is presented. Emphasis in the review is placed on 50 and 60 Hz electric fields, which cover the range of exposure near electric power transmission lines (several thousand V/m and magnetic fields less than 1 G) and fields of the same frequencies, which are typical of exposures from electric appliances and machinery (less than a few hundred V/m and magnetic fields greater than 1 G). The literature reviewed in the report involves diverse biologic systems, various methods of electric or magnetic field exposure, and many different responses. Although there

are cases where independent investigators have come to similar conclusions (for example, implying the importance of the extended cell membrane or discovering effects on the central nervous system), the overall picture remains incoherent. In part, the problem results from important differences in experimental design, which prohibit direct comparisons of the findings of different investigators. More work of high quality is required to augment the evidence that has resulted from several outstanding experimental inquiries.

- 5323 ENVIRONMENTAL EXPOSURES. (Eng.) Sheppard, A. R.; Eisenbud, M. In: *Biological Effects of Electric and Magnetic Fields of Extremely Low Frequency*. (New York: New York Univ. Press): pp (3) 1-9; 1977. (15 refs)

Environmental exposure to natural and man-made electric and magnetic fields in the extremely low frequency range is discussed. At a frequency of 50-60 Hz, the electric field of the natural background is of the order of 10^{-4} V/m and the natural alternating current magnetic background is about 10^{-8} G. Man-made fields are stronger than those of natural origin by many orders of magnitude. Typical 60-Hz fields vary from 3×10^{-3} V/m in rural areas to 10^{-1} V/m outside an electrified building to 10^{-1} - 10^{-2} V/m near electric appliances. Persons spending much time near high voltage equipment or working for power companies maintaining such equipment may be acutely exposed for several days a week to fields of several thousand V/m. Typical values for ambient 60-Hz magnetic fields range from about 10^{-3} to about 10 G, depending on proximity to appliances. Stronger magnetic fields occur near large magnets, electrical furnaces, or other equipment using high currents. The potential use of cryogenic or superconducting transmission facilities would introduce another localized source of strong magnetic fields.

- 5324 SPECIAL TOPICS. (Eng.) Sheppard, A. R.; Eisenbud, M. In: *Biological Effects of Electric and Magnetic Fields of Extremely Low Frequency*. (New York: New York Univ. Press): pp. (8) 1-32; 1977. (91 refs)

Special topics dealing directly or indirectly with the biologic effects of electric and magnetic fields in the extremely low frequency range are presented. The topics covered include the electric properties of cell contact membranes, the production of cataracts with electrical energy, the biologic effects of air ionization, surveys of persons exposed to high-voltage transmission lines, electric field effects on plant life, magnetic fields in the human body, the orientation of deoxyribonucleic acid in a magnetic field, the biologic effects of large magnetic fields (100-100,000 G), proposed mechanisms for the biologic effects of magnetic fields, the regulation of electric field exposure in the Soviet Union, and the development of regulations for magnetic field exposures in the United States and the Soviet Union.

5325 BIOPHYSICAL PRINCIPLES AND A BIOPHYSICAL
DESCRIPTION OF EXPOSURE TO ELF FIELDS.

(Eng.) Sheppard, A. R.; Eisenbud, M. In: *Biological Effects of Electric and Magnetic Fields of Extremely Low Frequency*. (New York: New York Univ. Press): pp (4) 1-28; 1977. (37 refs)

Biophysical relationships associated with exposure to extremely low frequency electric and magnetic fields are discussed. Topics covered include energy density in electric fields; dielectric properties and conductivity of biologic materials; electric field distortion by human bodies; electric fields inside the body; power loss inside the body; current flow into cells; cell size, shape, and membrane potential in an electric field; electrostatic induction; human capacitance; discharge effects; electrophoresis and dielectrophoresis; electromagnetophoresis; problems in dosimetry; and electric shock currents. When a body is placed in an external alternating current electric field, currents flow through the body, and the current density is uniform to the extent that the body is uniform. The interior electric fields necessary only to drive the interior current are smaller than the external field impinging on the surface of the body. The original field is distorted, and the fields at the body surface may be intensified several fold depending on the shape, position, and orientation of the particular surface. Reasonable estimates of the properties of cell membranes and the division of current between the cell and the surrounding solution show that only a small fraction of the current passes through the cell membrane so that the cell membrane potential is virtually unchanged by any reasonable external currents or fields. If there is an effect directly on the cell membrane, it must occur by means more subtle than a direct effect on the cell membrane potential. Moderately strong magnetic fields can cause circulating currents in the body comparable in magnitude to those induced by strong electric fields. The magnitude of currents induced by a magnetic field depends on the size of the current loop. For a circuitous path encompassing the dimensions of the body, the current density is greatest; whereas, over a very small volume in the body, the induced current density is very small. Because the magnetic permeability of living beings is essentially the same as for free space, the body appears transparent to magnetic fields. Therefore, the field is not perturbed, and all parts of the body experience the same field.

5326 SUMMARY. (Eng.) Sheppard, A. R.; Eisenbud, M. In: *Biological Effects of Electric and Magnetic Fields of Extremely Low Frequency*. (New York: New York Univ. Press): pp. (2) 1-37; 1977. (75 refs)

A summary of a review on the biological effects of electric and magnetic fields in the extremely low frequency range is presented. Topics covered include electric and magnetic fields in the environment, fields in the body, fields involved in normal biologic functions, the effects of external fields

on animals and humans (neurophysiological and behavioral, biochemical, clinical, physiological and behavioral, and reproductive), and the effects of strong external magnetic fields on biological systems. A long history of industrial experience with electric fields indicates that intermittent exposure to even the strongest of such fields has no obvious effect on health or sense of well-being, even after years of repeated exposure; however, this observation must be tempered by the fact that there has been no full scale epidemiologic study of utility workers. Compared with electric fields, magnetic fields associated with electrical currents may be an environmental factor of equal or greater importance. As with electric fields, a long history of exposures to magnetic fields of 50-60 Hz suggests that no obvious risks are associated with acute exposures to fields of moderately great strength (below 100 G); however, no scientific study among persons regularly exposed supports this observation. Evidence from human experimental investigations suggests that there may be biologic effects of uncertain significance at fields as low as 1 G. One firm conclusion that emerges from a review of the existing literature on extremely low frequency electric and magnetic fields is that relatively weak fields of this type are capable of evoking neurophysiological or behavioral effects. This is suggested by behavioral experiments on monkeys, biochemical studies on the calcium efflux in brain tissue, the experience of Soviet substation workers exposed to electric fields and the experience of other industrial workers exposed to magnetic fields, and by preliminary evidence for both electric and magnetic effects on the steroid hormones in animals.

5327 INTERNATIONAL TRENDS IN ELECTROMAGNETIC
RADIATION BIOEFFECTS RESEARCH (MEETING
ABSTRACT). (Eng.) Dodge, C. H. (Science Policy
Res. Div., Library of Congress, Washington, DC
20840); Zorach, G. R. *J Microwave Power* 12(1):
41; 1977. (0 refs)

The international literature (circa 1970-1975) on biologic and clinical phenomena associated with exposure to microwave and radio frequency electromagnetic fields (EMFs) is reviewed. Mechanisms by which EMFs exert their biologic effects are becoming better understood as investigative technology and methodology improve. Some recent evidence in the West supports Soviet and East European claims that EMFs can affect nervous system function and morphology in small mammals, birds, and invertebrates at power levels below those defined as thermogenic in the West. These experimental findings coupled with the pressure of public opinion may eventually lead to the establishment of revised occupational exposure limits and concurrence regarding maximum permissible exposures. At present, the level established in the Soviet Union is 0.01 mW/cm² for a work day, while the United States adheres to 10 mW/cm² averaged over 0.1 hr. However, Russian and East European reports of psychophysiological dysfunctions and impairment of a reversible nature as a result of chronic exposure to EMFs of relatively low power density (<10 mW/cm², and occasionally <1 mW/cm²) have not been

corroborated in the West. Additionally, there is no evidence to support speculation that modulated EMFs can be used to remotely control human behavior. Interaction between the concerned research and development communities in the East and West has increased substantially in the 1970's. Such interaction may enable resolution of differences in doctrine, experimental methodology, protocol, and the interpretation of biologic and clinical phenomena.

- 5328 EFFECTS OF ELECTRICAL FIELD STIMULATION ON ION TRANSPORT BY RABBIT ILEUM IN VITRO (MEETING ABSTRACT). (Eng.) Hubel, K. A. (Dept. Medicine, Univ. Iowa, Iowa City, IA). *Gastroenterology* 72(5, Part 2): 1072; 1977. (0 refs)

The effect of electric field depolarization of nerves on ion transport was studied in the intrinsic plexus of full thickness rabbit ileum mounted in a flux chamber. Unidirectional fluxes ($\mu\text{Eq/hr/cm}^2$) of ^{22}Na , ^{36}Cl , potential difference (mV), and short circuit current (SCC, $\mu\text{A/cm}^2$), measured during a 20-min control period, were contrasted with measurements made during a 20-min period of stimulation with current passed parallel to the mucosa for 30 sec of each min as a bipolar square wave of 10 Hz, 600 μsec duration, 600 msec/sec train. A second control period followed. The SCC increased, Cl was secreted, and the net flow of Na across the jejunum did not change significantly ($p < .05$). Cl was secreted because serosal to mucosal flow of Cl across the jejunum rose. To assess whether the changes were neurally mediated, tetrodotoxin (TTX, 10^{-7} M) was added to the bath fluid. TTX alone reduced the SCC and prevented the changes in Cl flux and SCC caused by electric stimulation. TTX did not prevent the increase in SCC caused by adding glucose to both sides of the mucosa, or the reduction in SCC caused by epinephrine (10^{-5} M). Electrical stimulation did not increase SCC when only muscularis was mounted, suggesting that the increment in SCC was not caused by ions moving passively in response to an asymmetric electric field. It is concluded that stimulation augments the SCC by increasing serosal to mucosal flow of Cl across the jejunum. The low concentrations at which TTX affects SCC (10^{-7} - 10^{-10} M) suggests that nerves mediate the response. TTX may affect liberation of hormones by paracrine or endocrine cells, or the transport of epithelial cells directly. If the latter is true, TTX does not affect ion transport systems that are sensitive to glucose or to epinephrine.

- 5329 POWER DENSITY ZONES IN THE VICINITY OF RADAR ANTENNAS (MEETING ABSTRACT). (Eng.) Plavcic, Z. (Coll. Aeronautical Engineering, Zagreb Airport, 41 150 Zagreb, Yugoslavia). *J. Microwave Power* 12(1): 44; 1977. (0 refs)

To evaluate potential radiation hazard in the vicinity of powerful radar stations, calculations of power density around the antenna were performed.

As a representative, a surveillance Radar LR-23 used in air-traffic control was examined. The radar peak power was 2.2 mW, the average power 2.64 kW, and the wavelength 23 cm. As a radiator, a reflector type antenna of high gain (36 dB) was employed. The space around the antenna could be divided into two regions. The near-field or Rayleigh region extended to the distance $R = 0.3 D^2/\lambda$, where D was the vertical dimension of the antenna and λ , the wavelength. In this region the power density on the antenna axis was constant and equal to $16P/\pi D^2$, where P was the transmitted power. For the evaluated radar, the near-field region extended to 106 m and the maximum average power density was 16.6 mW/cm². The power densities at various distances from the antenna in the far-field region also were calculated. The calculated values agreed with the experimental results. It is concluded that there is no radiation hazard in the areas accessible to the public, but special safety measures should be taken by maintenance and repair personnel working in close proximity to the operating radar antennas.

- 5330 MICROWAVE HYPERTHERMIA, CHEMOTHERAPY, AND CO-60 RADIATION IN THE TREATMENT OF HAMSTER MELANOMA (MEETING ABSTRACT). (Eng.) Traub, R. J. (Sch. Pharmacy and Pharmacal Sciences, Purdue Univ., West Lafayette, IN 47907); Vetter, R. J.; Stoetzel, G. A. *J. Microwave Power* 12(1): 40; 1977. (0 refs)

The effect of microwave hyperthermia alone and in combination with ^{60}Co radiation and a cytotoxic agent, *p*-fluorophenylalanine (PFP), on tumor growth rate and mortality in hamsters was investigated. Approximately 10^6 amelanotic melanoma cells were injected subcutaneously in the rear flank of golden hamsters. On the average, tumors reached a volume of 1 cm³ 10 days after injection. In all cases, animals were treated every other day for five treatments. Animals received a low temperature microwave treatment (2.450 MHz, 42-43 C for 12 min), high temperature microwave treatment (2.450 MHz, 44-47 C for 12 min), 25 mg/100 g PFP intraperitoneally, or sham microwave exposure (control). Microwave treatments were applied locally, and temperatures were measured immediately after treatment in the approximate center of the tumor. Preliminary observations revealed that the growth characteristics of the control tumors fit the typical sigmoidal growth curve. The tumor growth patterns in the PFP treated animals were similar to those of controls except the growth rate was slightly accelerated following the final PFP injection. The increased growth rate may have been due to toxicity of the PFP. The microwave treatments significantly disrupted the growth pattern of the tumors. Experiments on the synergistic action of all three agents are in progress.

- 5331 MORPHOLOGIC ALTERATIONS IN HAMSTER BLOOD-BRAIN BARRIER AFTER MICROWAVE IRRADIATION (MEETING ABSTRACT). (Eng.) Albert, E. N. (George Washington Univ. Medical Center, Washington, DC); Grau, L.; Kerns, J. *J. Microwave Power* 12(1): 43-44; 1977. (0 refs)

The morphologic effects of microwave irradiation on the blood-barrier of adult Chinese hamsters were investigated. The hamsters were divided into sham-irradiated control and irradiated experimental groups. Experimental animals were exposed to 2,450 MHz at 10 mW/cm² for 2-8 hr. Immediately following exposure, the animals were anesthetized with nembutal and injected with horseradish peroxidase via the femoral vein. Five min later, they were fixed by vascular perfusion with 1% paraformaldehyde-1.25% glutaraldehyde and stored in situ overnight at 4 C. The brains were dissected and incubated with 3-3' diaminobenzidine and hydrogen peroxide in Tris-HCl buffer, which formed a reaction product with the horseradish peroxidase. Tissues were subsequently post-fixed in osmium tetroxide, dehydrated, and embedded in Epon-Araldite. Alterations in the blood-brain barrier were recognized by locating regions of leakage in the microvasculature. Brown reaction product was visible at the gross and light microscopic level and appeared as electron dense material at the electron microscopic level. In control animals, extravascular reaction product was present only in brain regions normally lacking a blood-brain barrier (i.e., area postrema, pituitary, median eminence, and choroid plexus). In contrast, experimental animals showed extravasated reaction product in additional brain regions (i.e., cerebral cortex, hippocampus, thalamus, hypothalamus, cerebellar cortex, and medulla). At the ultrastructural level, horseradish peroxidase reaction product was present in the basal lamina of brain microvasculature and in the extracellular spaces around affected vessels. The effects may have been due in part to alterations in tight junctions in the capillary endothelium, which normally maintain the blood-brain barrier. Some glial cells contained reaction product in their cytoplasm, but this was not observed in neuronal cell bodies, dendrites, or axons. These observations suggest that the normally impermeable brain microvasculature can be rendered permeable to various degrees by microwave irradiation.

5332 HUMAN PERCEPTION OF MODERATE STRENGTH
LOW FREQUENCY MAGNETIC FIELDS. (Eng.)

Tucker, R. D. (Ph.D. dissertation, Univ. Minnesota, 1976); 106 pp. (available from Xerox Univ. Microfilms, Ann Arbor, MI 48106, Order No. 77-19,068). (27 refs)

Studies designed to determine whether subjects deprived of clues incidental to the generation of a magnetic field can successfully sense, or be taught to sense, the presence or absence of either uniform or gradient 60-Hz moderate strength magnetic fields are reported. Two different sets of Helmholtz coil systems were used for the experiments. A large coil system was capable of providing a uniform magnetic field (7.5 G root mean square, RMS) or field gradient (13 G RMS/m) in a man-sized space. The second or small coil system produced a uniform field (15 G RMS) or field gradient (70 G RMS/m) that was approximately head-sized. The experiments were conducted under both nonisolated and isolated conditions to determine the possible effects of audi-

tory vibrational clues on the subjects' responses. The results are interpreted as being compatible with either of two conclusions. The human subject may have a very weak sporadically-appearing ability to perceive magnetic fields, which is not strongly exhibited in any one individual or in any one series of tests. Alternatively, the subject may have no real field perception at all but is able over a long series of trials to get traces of mechanical, acoustical, or other undetermined clues that cannot be eliminated completely by isolation design. In both conclusions, the trace effects do not indicate an immediate health hazard.

5333 MICROWAVE HEATING EFFECT ON THE DOG THYROID GLAND. (Eng.) Magin, R. L. (Lab. Chemical Pharmacology, Div. Cancer Treatment, Natl. Cancer Inst., Bethesda, MD 20014); Lu, S-T.; Michaelson, S. M. *IEEE Trans Biomed Eng* 24(6): 522-529; 1977. (31 refs)

Dog thyroid glands were exposed in vivo to 2,450-MHz continuous wave microwave fields for 2 hr using a dielectrically-loaded waveguide applicator. Specific absorption rates of 58 ± 24 , 131 ± 44 , and 190 ± 45 W/kg in the center of the thyroid gland resulted in temperatures of 38-39 C, 40-42 C, and 44-46 C, respectively. Thyroid glands heated to 38-39 C showed a step-type increase in thyroxine release rate to twice equilibration period values. Thyroid glands heated to 40-42 C and 44-46 C showed peaks in thyroxine release rate after 50 min into the exposure period, which amounted to three times the equilibration period value for thyroid glands heated to 40-42 C and six times the equilibration period value for thyroid glands heated to 44-46 C. After these peaks, the thyroxine release rate fell for the remainder of the exposure period. The triiodothyronine release rate followed that of thyroxine for all temperature ranges tested. Unheated control thyroid glands maintained a temperature between 36-38 C and did not show significant increases in hormone release rate. A plateau in hormone secretion rate observed for thyroid glands heated to 38-39 C indicates continuous stimulation, showing a general increase in the gland's metabolism probably due to heating.

5334 MICROWAVE OVEN IRRADIATION AS A METHOD FOR BACTERIAL DECONTAMINATION IN A CLINICAL MICROBIOLOGY LABORATORY. (Eng.) Latimer, J. M. (Dept. Pathology and Pediatrics, Univ. Utah Coll. Medicine, Salt Lake City, UT 84132); Matsen, J. M. *J Clin Microbiol* 6(4): 340-342; 1977. (4 refs)

The use of microwave oven irradiation for bacterial decontamination in clinical microbiology laboratories was investigated. The exposure of 10 frequently isolated clinical pathogens to 2,450-MHz microwave irradiation resulted in total sterilization within 60 sec. Whereas, a vegetative culture of *Bacillus subtilis* showed no viable organisms after a 30-sec exposure to microwave irradiation, the time necessary to destroy 1.3×10^9 *B. subtilis*

spores/ml extended beyond 11 min. Exposure of *Bacillus stearothermophilus* strips to microwave irradiation resulted in sterilization after 5 min. Clinical isolates (including *Escherichia coli*, *Proteus mirabilis*, *Pseudomonas aeruginosa*, *Serratia marcescens*, *Staphylococcus aureus*, *Staphylococcus epidermidis*, and enterococcus) were killed by a 5-min exposure to microwave irradiation. Exposure of contaminated petri plates to microwave irradiation resulted in total sterilization within 5 min. The above data indicate that the utilization of microwave ovens for bacterial decontamination in clinical microbiology laboratories is entirely feasible.

- 5335 ELECTROMAGNETIC POWER DEPOSITION IN PROLATE SPHEROID MODELS OF MAN AND ANIMALS AT RESONANCE. (Eng.) Barber, P. W. (Dept. Bioengineering and Electrical Engineering, Univ. Utah, Salt Lake City, UT 84112). *IEEE Trans Biomed Eng* 24(6): 513-521; 1977. (15 refs)

The Extended Boundary Condition Method is used to calculate electromagnetic power deposition in prolate spheroid models of animals and man. The mathematical models consisted of homogeneous distributions of muscle tissue, although in the case of the human model calculations, a model consisting of homogenized muscle, fat, and bone was also considered. Calculations were made for bodies isolated in free space and irradiated by a plane wave. In general, three particular incident waves were considered—one from the end-on direction and two from the broadside direction. In the case of the human model, a resonant frequency of about 70 MHz was predicted for a 6.34:1 prolate spheroid muscle tissue model; the corresponding absorption efficiency was 3.7. For a human model of average homogenized tissue, the resonant frequency increased slightly, and the absorption efficiency increased to 4.6. A graphic representation of the average power absorption as a function of normalized dielectric constant (normalized to the dielectric constant of muscle tissue) for a 6.34:1 prolate spheroid muscle tissue man model due to an E-parallel broadside incident wave is presented. Over frequencies ranging from 10-70 MHz, it is suggested that it is more reasonable to use a dielectric constant for homogenized tissue than for muscle tissue alone. This is especially true at frequencies in the high frequency range where the curves are steeper than in the very high frequency range. At 10 MHz, for example, about 30% more power absorption would be expected for a model of homogeneous tissue than for one of muscle tissue.

- 5336 EFFECT OF 2,450 MHZ MICROWAVE RADIATION ON MICROORGANISMS. (Eng.) Wu, J. F. (Ph.D. dissertation, North Texas State Univ., 1977); 134 pp. (available from Xerox Univ. Microfilms, Ann Arbor, MI 48106, Order No. 77-19,694). (169 refs)

The effect of 2,450-MHz microwave radiation over a wide dose range on soil microflora was studied under

laboratory and field conditions. Radiation and thermal profiles showed that heterotrophic bacteria, spore-forming bacteria, fungi, and actinomycetes were not affected by exposure to a net microwave radiation input of 1 kW intensity over periods ranging from 0-80 sec. Nitrogen-fixing bacteria and nitrifying bacteria were also resistant to these doses. Soil microorganisms were inactivated by exposure to 1 kW of continuous microwave radiation over periods ranging from 80-480 sec. Resistance to microwave radiation was primarily associated with the degree of moisture content of the microorganism. The radiation appeared to leave no residual effect in the soil, and the microwave-induced effects on microorganisms seemed to be non-selective; the one exception was that fungi appeared more susceptible to microwave-induced inactivation. A heat-shock activation of microbial spores was observed during the experiments. The data imply that microwave treatment of agricultural fields for the purpose of killing weed seeds and insects has no effect on the soil microorganisms. Studies of the relationship between temperature generated in dry and wet organisms and the pattern of destruction of inoculated bacteria by microwave radiation revealed that inactivation was a function of cell hydration. Bacterial cells do not absorb microwave energy; the lethal effect of microwaves is due to direct energy transfer to cell water and to the temperature increase of the suspending medium.

- 5337 BIOLOGICAL EFFECTS OF X-BAND MICROWAVE IRRADIATIONS ON *E. COLI*. (Eng.) Hsieh, S. T. (Ph.D. dissertation, Tulane Univ., 1974); 155 pp. (available from Xerox Univ. Microfilms, Ann Arbor, MI 48106, Order No. 77-19,503). (65 refs)

Theoretical and experimental studies on the interaction of X-band microwave radiation with cellular metabolic systems under isothermal conditions are reported. Theoretic analysis derived a modified growth rate equation based on a spherical cell model of *Escherichia coli*. The aerobic growth rate was modified to include localization of the *E. coli* respiratory enzymatic system. With this model, an interaction analysis with electromagnetics predicted a radio frequency diffusion mechanism, which interfered with the cellular metabolism of *E. coli*. Other mechanisms, such as, radio frequency transport and induced membrane potential, were also implied. The incorporation of radio frequency diffusion effects with modified cellular growth predicted microwave-induced nonthermal effects on cellular respiration. Experiments with *E. coli* cultures, which were exposed to long-term, low-intensity X-band microwave radiation, were performed to verify the theoretic predictions. The cultures were incubated and exposed to microwave frequencies ranging from 7-12 GHz at power levels of 100, 60, 30, and 5 mW (or less). Microwaves consistently had definite effects on the deceleration growth phase of the cultures in the absence of temperature changes. A mathematic analysis of the experimental growth curves showed the frequency

response of such observed growth effects to be in good agreement with the theoretic predictions.

- 5338 EFFECT OF MICROWAVE ON STEROIDS PLASMA LEVELS IN MALE RATS (MEETING ABSTRACT). (Eng.) Deschaux, P. (Laboratoire de Physiologie Cellulaire, Université Claude Bernard 69621, Villeurbanne, France); Pelissier, J. P. *J Microwave Power* 12(1): 46-47; 1977. (0 refs)

The effects of microwaves on steroid plasma levels in male Sprague Dawley rats (C.D. strain) were studied. The animals (60 days old) were irradiated by microwaves (2,450 MHz) for 24 hr. After irradiation they were divided into four groups of five; controls were treated similarly without radiation. At sacrifice (10 min [1st group], 3 days [2nd group], 8 days [3rd group], and 15 days [4th group]), the rats were decapitated in an adjacent room within 15 sec after removal of their case. Systematic blood was collected, centrifuged, and the plasma was removed and stored at -20 C until assayed. Testosterone was determined by radioimmunoassay. The plasma samples were extracted with ether, and the dried extract was chromatographed on a cellite column to separate the dihydrotestosterone from testosterone. Plasma corticosterone level was determined by competitive binding radioassay. The plasma testosterone level was significantly higher in animals until 8 days (at 3 days $p \leq 0.05$; at 8 days $p \leq 0.1$); at 10 min and 15 days there was no significant difference. The plasma corticosterone level was significantly modified by microwave irradiation in the first 3 min. It is concluded that microwaves have specific receptors on particular organs in the organism.

- 5339 BOLUSING TECHNIQUE FOR BATCH MICROWAVE IRRADIATION OF TUMORS IN THE FAR FIELD (MEETING ABSTRACT). (Eng.) Cheung, A. Y. (Univ. Maryland Sch. Medicine, Baltimore, MD 21201); McCulloch, D.; Robinson, J. E.; Samaras, G. *J Microwave Power* 12(1): 42-43; 1977. (0 refs)

A technique for batch irradiation of superficial tumors in mice for microwave-induced hyperthermal cancer therapy was developed. Tumor-bearing mice were enclosed individually in a shield, with the tumor drawn through a slot for placement in the microwave heating field. To achieve replicable and uniform heating in the tumor, it was encapsulated in a much larger (60 g) "bolus" of tissue-equivalent material. For the size of bolus used (5 cm diameter of simulated brain) microwave energy deposition was peaked at a central site where field gradients were small. When a tumor was encapsulated at this site, steady state heating was uniform to within ± 0.1 C at 45 C. When unencapsulated, the tumor was difficult to heat due to poor field coupling and temperature was grossly non-uniform (± 1 C at 40 C). For batch irradiation, a standardized bolus geometry enabled heating to be nearly independent

of tumor size, provided that the mass of the bolus was much larger than the mass of the encapsulated tumor and the tumor-bolus system was on an equipower surface in the far-field. Simultaneous microwave treatment of up to 12 animals with encapsulated tumors was possible by exposing the animals on equal power density contours in a 2.5 x 2.5 x 2.5 m anechoic chamber. The animals were spaced 2 wavelengths apart and confined to a far-field area approximately 1 m². One site was reserved for a range calorimeter to monitor temperature.

- 5340 INTERDISCIPLINARY AND INTERNATIONAL CONTRIBUTIONS TO ELECTROMAGNETIC BIOLOGICAL-EFFECTS RESEARCH: PAST PERFORMANCE AND CHALLENGES FOR THE FUTURE. (Eng.) Johnson, C. C. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 2; 1977. (0 refs)

Interdisciplinary and international contributions to electromagnetic biologic effects research are highlighted. Teams of biologists, physicists, and engineers have developed a variety of small non-metallic thermal sensors for measuring tissue temperatures during electromagnetic radiation. Major progress has been made in investigating with precision the absorption of electromagnetic energy in models of animals and man at different frequencies and orientations. A region of "resonant" absorption has been identified near 70 MHz for the case of man exposed to a polarized field in free space. Extrapolation from data on animals to man is now possible, allowing specifications to be made of fields that will produce comparable effects in man. In Western countries, notable achievements have been made in research on thermal effects, instrumentation, and dosimetry, and Eastern countries have pioneered in and emphasized studies of long-term low-level irradiation, basic biologic mechanisms, behavioral and central nervous system functions, and epidemiologic phenomena. The establishment of interdisciplinary research teams and the availability of new engineering tools and techniques will enable identification of hazardous interactions, discovery of basic mechanisms, extrapolation of infra-human data to man, and development and extension of medical applications of electromagnetic energy.

- 5341 SOME PERSPECTIVES ON RESEARCH INTO THE BIOLOGICAL RESPONSE TO NON-IONIZING ELECTROMAGNETIC RADIATION. (Eng.) Sharp, J. C. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 3; 1977. (0 refs)

The relationship between what types of research are supported and the socio-political milieu of funding agencies is discussed. Past and future programs are used as examples of how emphasis is, or could be, altered by the changing philosophies of the federal establishment. An attempt is made to demonstrate how the operating philosophies of past decades have dampened the desire and ability to investigate electromagnetic energy coupling with biologic material. Some implications of adhering to these trends for the scientific community and for the public are outlined.

- 5342 AN INVESTIGATION OF THERMISTORS FOR TEMPERATURE MAPPING OF BIOLOGICAL SPECIMANS DURING EM RADIATION (MEETING ABSTRACT). (Eng.) Toler, J.; Burdette, E.; Seals, J.; Cain, F. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by the International Union of Radio Science & The U.S. Committee for URSI held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 6; 1977. (0 refs)

A series of experiments was undertaken to determine the suitability of bead thermistors as thermometric devices. Such devices have not been widely used for bioeffects studies because of the possibility of excessive interaction with electromagnetic (EM) fields. The accuracy and repeatability of temperature data provided by both standard and micro-miniature thermistors were examined. The thermistors had conventional leads, and the frequency of radiation was 2,450 MHz. Variables included EM field-strength, thermistor location, cannula configuration, and electrical properties of the implanting medium. The results reveal that, for many studies of biologic effects, bead thermistors provide accurate and repeatable temperature data.

- 5343 RESPONSE OF INSULATED ELECTRIC-FIELD PROBES IN MODELS OF HETEROGENEOUS BIOLOGICAL BODIES (MEETING ABSTRACT). (Eng.) Mousavinezhad, H.; Chen, K. M.; Nyquist, D. P. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 10; 1977. (0 refs)

The response of an idealized spherical metallic probe, insulated by a dielectric layer and immersed in a semiconducting biologic body (both spherical and concentric with the probe) was studied. The idealized probe was representative of more general electric-field probes. Analytic expressions for the effective diameter d_{eff} and equivalent impedance Z_{eq} of the probe were determined in terms of the radii and electric parameters of the insulating layer and of the finite body. Numeric results indicated that variations of the probe's parameters

d_{eff} and Z_{eq} (calibration factor) were minimized by coating the probe with a relatively thick insulating layer of low permittivity. Comparison of theoretically calculated induced-power-density distribution with those measured by an insulated spheric probe in a finite volume of saline solution revealed excellent agreement at all locations in the solution. The relative constancy of the calibration factor for the insulated probe was therefore confirmed.

- 5344 CARBON ELECTRODES FOR CHRONIC EEG RECORDINGS IN MICROWAVE RESEARCH (MEETING ABSTRACT). (Eng.) Chou, C. K.; Guy, A. W. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 11; 1977. (0 refs)

Conventional metal electrodes can cause serious modification and intensification of rate of energy absorption in tissues during exposures of animals to microwaves. Carbon-impregnated Teflon with a conductivity close to that of tissue was implanted and maintained for 4 to 6 mo in rabbits at cortical and subcortical locations. The electroencephalogram (EEG) and its spectrum, as recorded from the carbon electrodes, were comparable to those recorded from conventional metal electrodes. Histologic examination showed good tissue compatibility. Recordings during acute microwave radiation (2,450 MHz) at 100 mW/cm² showed no interference. The results indicate that carbon electrodes can be implanted chronically to record the EEG in animals during microwave radiation.

- 5345 VARIABILITY IN MICROWAVE MEASUREMENTS OF CATARACTOGENIC THRESHOLD (MEETING ABSTRACT). (Eng.) Hagan, G. J.; Donovan, G. L.; Carpenter, R. L. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: p. 13; 1977. (0 refs)

Measurements of identical microwave fields were performed under identical conditions using several different instruments. Measurements were made in a large, electrically anechoic chamber with continuous wave radiation at 2.45 GHz. The instruments tested were four Narda Model-8100 radiation meters with five Model-8122A probes, two Narda Model-8315 broadband-isotropic radiation monitors with Model-8323 probes, and one Holaday HI-1500 microwave survey meter. Power-density values yielded by two of the Narda-8100 meters, which were calibrated just before use, served as a standard of comparison for the other instruments, which had been calibrated at various times during the previous 20 mo. In the far-zone field, 150 cm from a horn antenna, each set of probes and meters that had been calibrated together,

were tested. Their readings varied 0.4 to 37.7% from the standard. Near-zone fields were measured 5 cm in front of the Director "C" dipole-antenna applicator of a Raytheon Microtherm diathermy unit. Readings of power density at this position with the Narda Model-8122A probes were significantly lower (30%) than those of the Model-8323 probes. The difference may have been due to the differing size of the probes' sensors or to a longitudinal (or radial) component in the field of the Director "C" that was not detected by the Model-8122A probe. Rotating a probe around its long axis and taking meter readings at each 90 degrees of rotation resulted in deviations that were more pronounced for measurements in the near-zone.

- 5346 MINIATURE ANECHOIC CHAMBER FOR CHRONIC EXPOSURE OF RODENTS TO PLANE-WAVE MICROWAVE FIELDS (MEETING ABSTRACT). (Eng.) Guy, A. W. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 16; 1977. (0 refs)

An economic system was developed for exposing large numbers of rodents to 2,450-MHz plane waves on a long-term basis without disturbing their normal living patterns. Individual miniaturized anechoic chambers provided a relatively constant and easily quantifiable coupling of microwave fields to each animal. A food-and-water dispensing system was designed to prevent the introduction of artifacts when the animal ate or drank.

- 5347 CIRCULARLY POLARIZED 2450-MHZ WAVEGUIDE SYSTEM FOR CHRONIC EXPOSURE OF RODENTS (MEETING ABSTRACT). (Eng.) Guy, A. W.; Wallace, J. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 17; 1977. (0 refs)

A system that was previously developed to expose a large number of rodents to 915-MHz circularly polarized fields was modified to operate at 2,450 MHz. Specially designed transducers were retrofitted to each end of the original exposure system, and the probes and hybrid transducers normally required to operate the system at the lower frequency were removed. The conversion of each exposure cell to another frequency of operation was accomplished in a few minutes. The performance of the cells at 2,450 MHz in terms of coupling efficiency and low input VSWR was found superior to that obtained at 915 MHz.

- 5348 IMPROVING FAR-FIELD UNIFORMITY IN NONIDEAL MICROWAVE ANECHOIC CHAMBERS BY ADDING ABSORPTIVE COLLAR TO FEEDHORN (MEETING ABSTRACT). (Eng.) Olsen, R. G.; Lotz, W. G. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 18; 1977. (0 refs)

Improved uniformity of far-field power density by the addition of microwave-absorbing feed-horn collars is described. The addition of an absorptive collar around the aperture reduces the unwanted interference resulting from the use of fixtures and/or instruments that must be located in the irradiation chamber. While the collar contributes some interference of its own, the net result is a significant improvement in the uniformity of the distribution of far-field power densities. Two microwave chambers were analyzed. One chamber contained video and lighting equipment; and the other, in addition, an overhead motorized x-y scanning apparatus. It is hypothesized that horn collars improve uniformity of radiation in the far-field by reducing side-lobe radiation.

- 5349 LONG-TERM MICROWAVE EXPOSURE OF MARINE ANIMALS (MEETING ABSTRACT). (Eng.) McRee, D. I. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 19; 1977. (0 refs)

Long-term (1- to 2-mo) studies of the effects of microwaves on the behavior of the marine mollusc *Aplysia californicus*, were performed using three groups of animals (of four animals each) at three different microwave levels (20.0, 2.0, and 0.0 mW/g at 2,450 GHz continuous wave) within the same 25-gallon aquarium. The animals were placed in flat (less than 2-cm thick) plastic screen cages that were suspended at different distances (1.0 cm, 3.0 cm, and 15.0 cm with respect to the mid-cage plane) from the front window of the aquarium on which microwave energy was incident (from a standard gain horn located 1.2 m away). Microwave energy reflected from the front of the aquarium was controlled by the "Eccosorb" lining of the chamber. Since mollusc tissue is similar electrically to sea water (as confirmed by reflectometric measurements), no reflection occurred within the aquarium, and the animals did not cast "absorption shadows" over one another. The specific absorption rate for any volume could be computed irrespective of the animals' location (or even their presence). This exposure system also provided thermal stability in the face of large inputs of microwave energy. The thermodynamically-regulated cooler built into the aquarium was able to dissipate a maximum of 1,000 W at a temperature swing of 2 C or less. Furthermore,

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since the circulating sea water acted as an efficient heat exchanger, the steady-state temperature differences among groups of animals could be kept to 1 C or less. It is concluded that this system overcomes many of the dosimetric difficulties encountered in the long-term microwave radiation exposure of terrestrial animals.

- 5350 A SYSTEM FOR THE EXPOSURE OF LARGE NUMBERS OF SMALL LABORATORY ANIMALS TO 60-HZ ELECTRIC FIELDS (MEETING ABSTRACT). (Eng.) Kaune, W. T.; Decker, J. R.; Phillips, R. D.; Hjerlesen, D. L. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 20; 1977. (0 refs)

Two systems for exposure and sham-exposure of large numbers of rats and mice to uniform vertical 60-Hz electric fields were constructed. The rat system contained four racks of four rectangular 1.0 x 2.2 m exposure-electrodes stacked vertically with a 0.41 m separation between adjacent electrodes. Any two of the four exposure racks could be energized to a maximum field strength of 150 kV/m. Each exposure electrode was equipped with 24 Lexan cages, each of which housed a single rat. The cage floor was a stainless steel screen that served as one electrode. The system for watering animals was contained entirely within the electrode and did not protrude above the cage's floor, thereby preventing distortion of the exposure field and electrical shock or discharge as the animals drank. The total capacity of the system was 288 rats. A similar system of two racks of five electrodes each was used to expose as many as 450 mice to fields at a maximum strength of 150 kV/m while sham-exposing an equal number. Measurements of the electric field revealed an overall uniformity within 4% over the area to be occupied by experimental animals. The field inside a Lexan cage was reduced by about 3%. No corona-discharge was detected. Measurements of ozone concentration in the rat and mouse exposure systems did not differ from background levels. Harmonic distortion was eliminated by damping and filtering the high-voltage supply. Animals housed in close proximity were partially shielded from the electric field; the total body current in a rat model was reduced by $35 \pm 5\%$ when rats were placed in adjacent cages.

- 5351 A SYSTEM FOR CONTINUOUS EXPOSURE OF MINIATURE SWINE TO 60-HZ ELECTRIC FIELDS (MEETING ABSTRACT). (Eng.) Gillis, M. F.; Allen, C. H.; Beamer, J. L.; Jeffs, T. W.; Decker, J. R.; Phillips, R. D. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*.

Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 21; 1977. (0 refs)

A facility was constructed for the long-term study of effects of uniform vertical 60-Hz electric fields on miniature swine, including an environmentally similar enclosure for control animals maintained in a zero-level field. Exposure of this genealogically homogeneous generation was begun at 30 kV/m and progressed on a continuous basis as routine clinical data were gathered and special physiologic investigations were performed. From the first generation, a second was derived (exposed in utero) that was studied through development to adulthood. The colony, including controls, comprised 60 swine in individual stalls. A ground-level concrete pad formed the foundation, within which were flush-mounted or recessed receptacles for electrical power, water, and low-profile indirect-lighting fixtures. Two rows of contiguous swine stalls ran the length of the pad on either side of a central walkway and had electrically-grounded embossed steel flooring. The stalls were constructed of fiberglass-reinforced plastic (FRP) grating and nonconducting hardware. Over the pad and stalls was a quonset-type modular enclosure consisting of prefabricated panels held together by nylon bolts and sealed against moisture with silicone rubber and contact-cemented FRP strips. The panels consisted of two FRP sheets sandwiching a 5-cm layer of polyurethane foam, facilitating control of ambient environmental temperature. The panels also provided thermal insulation to prevent condensation of moisture, which might shield the animals from the field. Above the building were four parallel, large-diameter, cylindrical electrodes that, over the area occupied by swine, produced an unperturbed field of 30 kV/m when energized to 225 kV by a remotely located transformer. With the swine absent, the field 1 m above ground was constant in magnitude within 6% and, vertically, within 2% over the test area. Temperature, relative humidity, and electric-field strength were controlled and monitored continuously and automatically by instrumentation in a building outside a fence that surrounded the exposure facility. Environmental data were also recorded automatically by on-line computers that logged extrema and means over present intervals of time. The building also contained a small clinical facility and a video monitor that was connected to traveling video cameras for monitoring of experimental and control animals.

- 5352 POSSIBLE DETECTION IN VIVO OF LATENT VIRUSES IN TUMOR AND BACTERIAL CELLS AND THEIR INDUCTION BY MILLIMETER MICROWAVES (MEETING ABSTRACT). (Eng.) Webb, S. J. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 24; 1977. (0 refs)

The detection of latent viruses *in vivo* by microwave spectroscopy and the alteration of their effects on the behavior of cells following microwave radiation exposure were studied. Microwave and laser-Raman spectra of naturally-occurring tumor cells and of bacteria indicated that, as a result of active metabolic processes, resonances occur *in vivo* between 10^{10} - 10^{11} Hz. The resonances were not present in inactive cells, dead cells, or homogenates of cells. The microwave absorption spectra of normal human mammary tissue contained five strong peaks between 65 and 95 GHz, four of which were present in mammary carcinoma tissue and in "normal" tissue from diseased patients. Each of these peaks, however, was split into two or three sub-peaks. In addition, the spectrum of carcinoma tissue contained a broad, double-spiked peak at 76 GHz. Similarly, the spectrum of normal cells from the kidney of the baby hamster (BHK) contained four major peaks between 65 and 95 GHz that became broadened and double-peaked as the cells were transformed into tumor cells by infection with mouse sarcoma virus (MSV). The spectrum of *Escherichia coli* K12 (ATCC 12345) also displayed four major peaks between 68 and 95 GHz, each of which became double- or triple-spiked when the microbe was lysogenized with a temperate lambda bacteriophage. The attenuation of frequencies depended, however, on the age and nutritive state of the cells. The laser-Raman spectra between 10 and 200 cm^{-1} of both the mammalian and bacterial cells also contained strong single peaks that shifted and became double- and triple-spiked when the cells were injected with latent or temperate viruses. This double-spiked nature of the Raman lines disappeared when BHK tumor cells were irradiated by microwaves at 76 GHz; the irradiation caused the cells to lose their oncogenic properties but not their viability. The same loss of double-spiked Raman lines occurred when lysogenic bacterial cells were irradiated at 70.5 GHz; however, many of the prophages were induced, and lysis of cells resulted. The mechanism of prophage induction by microwaves did not appear to be thermal as no significant rise of temperature occurred. Irradiation of tumor cells resulted in loss of oncogenic characteristic but not viability. These results indicate that latent viruses may be detected *in vivo* by microwave spectroscopy and that their effects on the behavior of cells can be altered by exposure to microwave radiation at specific frequencies.

- 5353 MICROWAVE EFFECTS IN *DROSOPHILA MELANO-
GASTER* (MEETING ABSTRACT). (Eng.) Dardal-
hon, M.; Berteaud, A. J.; Averbeck, C. In: *Ab-
stracts of 1977 International Symposium on the Biolog-
ical Effects of Electromagnetic Waves*. Sponsored
by The International Union of Radio Science & The
U.S. Committee for URSI, held at Airlie, VA on
October 30, 1977-November 4, 1977: pp. 25; 1977.
(0 refs)

Irradiation of *Drosophila melanogaster* in the free-
field of millimeter (73 GHz) and centimeter (17 GHz)

microwaves was performed. Wild-type Paris strain and the tumor strain δ -carrying melanotic tumors in the third larval stage, in the pupal stage, and as adults were used. Maximum route-mean-square power densities were 100 mW/cm^2 for 73-GHz energy and about 60 mW/cm^2 for microwaves at 17 GHz. After 2 hr of exposure to microwaves at either frequency, both the hatching rate and the development of irradiated eggs were normal. Survival rates at varying stages of development were not statistically different. The microwave treatment did not induce teratologic changes in adults or alterations in the incidence and multiplicity of tumors. When wild-type females that were exposed to microwaves at 17 GHz for 21 hr were crossed with untreated males, a marked increase in fertility was observed. Viability and incidence of tumors in descendents were not affected.

- 5354 EFFECTS OF MILLIMETER WAVES ON LIVING
TISSUE (MEETING ABSTRACT). (Eng.) Gandhi,
O. P.; Hill, D. W.; Partlow, L. M. In: *Abstracts
of 1977 International Symposium on the Biological
Effects of Electromagnetic Waves*. Sponsored by The
International Union of Radio Science & The U.S. Com-
mittee for URSI, held at Airlie, VA on October 30,
1977-November 4, 1977: pp. 26; 1977. (0 refs)

A solid-state computer-controlled system was devised for swept-frequency measurements of absorption spectra of biologic specimens over a range of frequencies from 26.5 to 90 GHz. Biologic preparations were held in a thin-walled (thickness less than $\lambda_g/100$ at the center frequency) rectangular glass tube inserted through a nonradiating slot in the narrow wall of the waveguide. The sample, filling the entire cross section of the waveguide, was of a thickness on the order of one-tenth of the free-space guide wavelength λ_g . Power levels that produced less than a 0.1 C temperature elevation during a 2-min period of irradiation were employed. The incident, reflected, and transmitted powers were measured, digitized, and stored at frequency intervals of 0.05 GHz. The absorption of the sample was then calculated and plotted using an on-line X-Y plotter. Measurements of the dielectric properties in this band of various biologic preparations are reported. Absorption spectra are presented for relevant biologic compounds (water, proteins, DNA, RNA, etc), biologic solutions (minimal essential medium, saline, Luria broth, etc.), and cell suspensions (normal and transformed cells, bacteria, yeast, etc.) in aqueous solutions. In addition, data concerning biologic action spectra are presented on the viability, growth, viral infectivity, and morphology of irradiated cells.

- 5355 MEASUREMENT OF THE ELECTRICAL PROPERTIES
OF BIOLOGICAL LIQUIDS AT FREQUENCIES BE-
TWEEN 1 AND 100 GHZ (MEETING ABSTRACT). (Eng.)

Grant, E. H. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 27; 1977. (0 refs)

Techniques for measuring the complex permittivity of biologic fluids between 1 and 100 GHz are described. The principal constituent of biologic liquids, water, has an attenuation coefficient approximating 0.2 cm^{-1} at 2.45 GHz, which increases to more than 30 cm^{-1} at 70 GHz. The accompanying decrease in permittivity is from ~ 80 to 11. These radical variations over a relatively small range of frequencies require the use of methods appropriate to liquids of low or medium loss (depending on ionic conductivity) at frequencies of a few GHz and, in contrast, require traveling wave techniques specifically devised for high-loss liquids at frequencies near 100 GHz. As an example of each type of technique, data were presented on blood at various concentrations of hemoglobin, as measured at 2 GHz, along with results for water, at 70 GHz. The measurements on blood were consistent with a hemoglobin hydration (bound water content) of 0.35. The values of permittivity at 70 GHz showed that water at 0°C has an infinite frequency permittivity of 5.05 ± 0.03 and a Cole-Cole distribution parameter attenuation coefficient of 0.05 ± 0.015 that decreases with temperature.

5356 ABSENCE OF ECG AND RESPIRATORY CHANGES IN TURTLES AND TORTOISES EXPOSED TO MICROWAVE FIELDS OF LOW DENSITY (MEETING ABSTRACT). (Eng.) Flanagan, W. F.; Lowell, W. R.; Seeley, R. L. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 31; 1977. (0 refs)

Six specimens each of *Chrysemus picta* (all females; 15.4-16.5 cm in length), *Gopherus agassizii* (1 male, 5 female; 17.2-24.2 cm), and *Terrapene carolina* (4 male, 2 female; 14.7-17.0 cm in length) were implanted with carbon-loaded Teflon electrodes for monitoring of electrocardiogram (ECG) and respiration. Electrode tips were inserted 2-3 mm between upper shell and underlying soft tissue. Following recovery, animals were restrained and individually exposed to continuous wave (CW) or to pulsed wave (PW) 960-MHz fields (\vec{E} parallel to spine) at peak power densities of 0.1 mW/cm^2 ($0.01\text{--}0.06\text{ W/kg}$ specific absorption rate, SAR), 3.0 mW/cm^2 ($0.4\text{--}1.6\text{ W/kg}$), 7.0 mW/cm^2 ($0.9\text{--}3.8\text{ W/kg}$), or 10.0 mW/cm^2 ($1.3\text{--}5.5\text{ W/kg}$). Groups of six animals (two/species) were randomly assigned to exposure periods of either 5, 30, or 90 min. Half of each group (one/species) was exposed to CW and half to PW radiation; 24 hr later, exposure condition was reversed. Exposure periods, each at a higher power level, were preceded by non-exposure periods of the same duration. Animals were habituated to restraint for 1 hr prior to the initial nonexposure period. Averaged heart rates and inter-

respiratory intervals between exposure periods and preceding nonexposure periods were not statistically different. Exposure trends at the levels of species and of specimens were not apparent. Absence of ECG-changes in intact animals contrasts with reports of bradycardia in hearts isolated for *C. picta* at an SAR of 2 W/kg when exposed to CW, 960-MHz radiation. It is suggested that compensatory mechanism(s) may be present in the intact animal to prevent bradycardia, or bradycardia may occur uniquely in the isolated-heart preparation.

5357 HEART-RATE MODIFICATION IN VIVO FROM IRRADIATION BY ELECTROMAGNETIC ENERGY (MEETING ABSTRACT). (Eng.) Eichert, E. S.; Frey, A. H. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 32; 1977. (0 refs)

Heart rate modification was studied in frogs (*Rana pipiens*) irradiated by pulse-modulated ultra high frequency (UHF) energy. One group of frogs received alternate 10-min periods of sham exposure and exposure that was synchronized to produce radiation of the heart during the rise of the R-wave of the electrocardiogram. Another group received alternate 10-min periods of sham exposure and exposure that was synchronized for radiation of the heart during the T-wave. The final group was used as an absolute control and received alternate periods of sham irradiation only. Modulated ultra-high-frequency energy at 1.25 GHz with a peak power of 50 mW/cm^2 and a pulse width of $5\text{ }\mu\text{sec}$ produced tachycardia when synchronized with the rise of the R-wave. Results on T-wave synchronization were inconclusive.

5358 INTERACTION OF THE NEURON WITH ALTERNATING CURRENT FIELDS (MEETING ABSTRACT). (Eng.) Musil, J. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by the International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 33; 1977. (0 refs)

To investigate the possibility of a direct interaction of electromagnetic waves and the neuron, a method was devised to study properties of the cell by means of models that treat the cell as a geometrically closed formation with distributed parameters. Specific properties of mono- and poly-frequency responses were verified experimentally. The properties were expressed in a form that permitted determination of equivalent circuits.

5359 THE EFFECT OF ELECTROMAGNETIC ENERGY ON SPONTANEOUS CONTRACTIONS OF SMOOTH MUSCLE (MEETING ABSTRACT). (Eng.) Whitcomb, E. R.; Weil, C. M. In: *Abstracts of 1977 International Symposium*

on the Biological Effects of Electromagnetic Waves. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 36; 1977. (0 refs)

The effect of radio frequency electromagnetic energy on the rate of spontaneous contractions of smooth muscle of isolated rat gut was measured. A segment of the duodenum was suspended in a 10-ml plastic tube that was mounted in a capacitive-plate exposure-device that operated at 1 GHz continuous wave. The gut segment was continuously bathed with modified Ringer's solution (pH 7.5, at 35 C) with a flow of 40 ml/min as pumped from a 400-ml reservoir. The preparation was equilibrated in Ringer's solution for 1 hr at 7 C and 1 hr at 36 C prior to recording. Gut segments from four male adult rats were used at each exposure level. The energy absorbed by the medium was calculated by measuring the temperature rise of the Ringer's solution in the plastic tube. Exposures were made at specific absorption rates of 0.8, 1.7, and 3.6 mW/g. For each trial, 500 contractions were recorded with the microwave generator in a stand-by position. This was followed by measuring 500 additional contractions during radiation at selected intensities. Isometric contractions were monitored by a Statham transducer and were recorded on magnetic tape. A data retrieval computer was used to plot the rate of contraction as an interval histogram pattern (IHP). The IHPs did not indicate any significant difference between the rate of contraction during the control and exposure periods. Therefore, exposure of isolated rat gut to radio frequency radiation did not produce a measurable effect on the spontaneous rate of smooth muscle.

5360 EFFECTS OF MICROWAVE RADIATION ON THE RAT'S PITUITARY-THYROID AXIS (MEETING ABSTRACT). (Eng.) Lu, S.-T.; Lebda, N.; Michaelson, S. M. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 37; 1977. (0 refs)

Young adult rats (after acclimation to experimental procedures) were exposed to 2,450-MHz continuous wave radiation at 1 to 20 mW/cm² for 1 to 8 hr. The increase in colonic temperature of rats was found to be the most sensitive parameter measured. Elevation of temperature was observed in rats after exposure at 1 mW/cm² for 4 hr. Circulating thyrotropin (TSH) levels were depressed in rats exposed at 10 mW/cm² for 1 or 2 hr. However, the depression did not affect levels of circulating thyroxine (T₄) after as much as 8 hr of exposure at this power density. Rats exposed at 20 mW/cm² showed lower TSH levels than sham-exposed rats after 2 and 8 hr of radiation. The lower TSH levels were accompanied by T₄ depression after 4 and 8 hr exposure. Increased TSH levels were not observed. However, there was a transitory increase in T₄ levels in rats exposed at 1 mW/cm² for 4 hr.

These observations indicate that exposure to microwaves can stimulate thyroidal activity and can suppress secretion of thyrotropic hormone through an "open-loop" mechanism as part of thermoregulatory activity.

5361 EFFECTS OF HYPOPHYSECTOMY AND DEXAMETHASONE ON THE RAT'S ADRENAL RESPONSE TO MICROWAVE IRRADIATION (MEETING ABSTRACT). (Eng.) Lotz, W. G.; Michaelson, S. M. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 38; 1977. (0 refs)

In an attempt to determine if microwave-induced increases in plasma corticosterone of rats are due to a primary stimulation of the adrenal gland, hypophysectomized and dexamethasone-pretreated rats were exposed to 2,450 MHz continuous wave radiation. The animals were exposed in the far field of a horn antenna for 60 min at 50, 60, or 70 mW/cm², with corresponding averaged absorption rates of 8.0, 9.6, or 11.2 W/kg. Immediately after exposure, the rats were decapitated; blood was collected; and colonic temperature was measured. Plasma samples were assayed for corticosterone. The increases of corticosterone that were present in intact and sham-hypophysectomized rats after a 60-min exposure at 60 mW/cm² (9.6 W/kg) were totally absent in hypophysectomized rats. The effect of dexamethasone on the corticosterone response to a 60-min exposure at 50 mW/cm² (8.0 W/kg) depended on the dose of dexamethasone. Administration of 5.6 or 10.0 µg/100 g of body mass effectively blocked the increases in corticosterone that were observed in sham-injected rats. The results indicate that the adrenal gland is not primarily stimulated by microwave exposure but is stimulated secondarily by adrenocorticotrophic hormone that is secreted during exposure to microwave radiation.

5362 GROWTH HORMONE LEVELS OF RATS EXPOSED TO 2450-MHZ (CW) MICROWAVES (MEETING ABSTRACT). (Eng.) Lotz, W. G.; Michaelson, S. M.; Lebda, N. J. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 39; 1977. (0 refs)

Growth hormone (GH) was measured in plasma samples obtained from unanesthetized male rats exposed to 2,450-MHz continuous wave radiation. The rats were exposed in the far field of a standard gain horn-antenna for 30 or 60 min at power densities of 0, 13, 20, 30, 40, 50, or 60 mW/cm², or for 120 min at 0, 13, 20, 30, or 40 mW/cm². The averaged energy absorption rate, as measured calorimetrically with a 290-ml water load, was 0.16 W/kg absorbed per mW/cm² of incident radiation. Immediately after exposure, the rats (four exposed and two controls) were decapitated; their blood was collected; and colonic temperature was taken. GH was assayed by

radioimmunoassay. Significant increases in colonic temperature of the exposed rats were observed after all exposures of 13 mW/cm² or greater; larger increases were seen at each successively greater power density. For 30- and 60-min exposure, GH levels were lower than control values only at 50 and 60 mW/cm². For 120-min exposure, GH levels were lower than those of controls after exposures at 13 mW/cm² or higher, with progressively lower GH values observed at each successively greater power density. With respect to exposure duration, GH levels showed a trend toward lower values with longer exposure durations at each power density ≥ 13 mW/cm². In contrast, the GH levels of control animals were higher after 120 min than after the two shorter durations of sham-radiation. The effects of microwaves on GH-levels were, in general, physiologically analogous to the influence previously reported on the plasma corticosterone levels of rats.

- 5363 EFFECTS OF HANDLING AND SURGICAL TREATMENT OF CONVULSIVE LATENCIES AND MORTALITY OF TUMOR-BEARING RATS TO 2450-MHZ MICROWAVE RADIATION (MEETING ABSTRACT). (Eng.) Justesen, D. R.; Morantz, R. A.; Clark, M.; Reeves, D.; Mathews, M. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 40; 1977. (0 refs)

Hyperthermia as induced by 2,450-MHz whole-body radiation in a multi-mode cavity is being assayed as an experimental treatment of a surgically-seeded neoplasm in the brain of the Fischer-244 rat. The aim of this study was to produce the maximal elevation of brain temperature that is compatible with survival and non-debilitation. Sixty mature male rats were assorted in equal numbers to 1 of 12 possible treatments in a randomized factorial study that controlled for handling (minimal handling versus seven daily periods of "gentling" and exploration of inert cavity), radiation (0 or 100 mW/g dose rate), and surgical treatment (cage control vs. surgery with implanting of vehicle only vs. surgery with implanting of malignant glioma). The primary end-point was latency-to-convulsion. Secondary end-points were body temperature, mortality, and hygienic status of the animals as indexed by body mass. It was found that while handling reliably reduced variability of convulsive latencies of caged animals, it combined with the stresses of surgical treatment and radiation to produce severe debilitation. Additionally, acute mortality from radiation was zero in caged controls but approximated LD₅₀ in surgically treated rats. The implication of these findings is that the stresses of near-concomitant handling, surgery, and radiation are additive; the practice of "gentling" can markedly limit the therapeutic dosage of radiation.

- 5364 CATARACTOGENIC RESPONSE OF RABBITS TO PULSED MICROWAVES OF HIGH-PEAK LOW-AVERAGE

POWER (MEETING ABSTRACT). (Eng.) Ferri, E. S.; Foti, M. E. G. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 41; 1977. (0 refs)

The potential risk of lenticular damage following continuous microwave exposure was compared to that resulting from pulsed microwave irradiation. The cataractogenic threshold in response to pulsed microwave radiation at high peak low average powers and at a frequency of 2.9 GHz was ascertained. The threshold was compared to that obtained at a frequency of 2.45 GHz of continuous wave radiation. There were no significant differences between thresholds. It appears that no greater hazard to the eye is associated with radiation delivered via the pulsed mode as opposed to the continuous. A correlational analysis of three frequencies and their respective ocular reactions also is presented and interpolated. The energy distribution of focused microwaves behind a dielectric lens at a frequency of 2.9 GHz was contrasted with that obtained at 2.45 GHz and 10 GHz. Results further support the previous experimental conclusion that cataractogenic potential varies inversely with microwave frequency.

- 5365 RADIOFREQUENCY RADIATION DOSIMETRY HANDBOOK: DESCRIPTION OF THE SECOND EDITION (MEETING ABSTRACT). (Eng.) Durney, C. H.; Johnson, C. C.; Barber, P. W.; Massoudi, M. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 44; 1977. (0 refs)

The first edition of the *Radiofrequency Radiation Dosimetry Handbook* included specific absorption rate (SAR) data as a function of frequency for a variety of experimental animals and humans under various configurations both for plane waves and for a limited number of non-plane-wave fields. A second edition of the handbook will include experimental data, modeling, extended frequency range, scattering effects, data on biologic response to heating, and ground-plane effects.

- 5366 A TECHNIQUE FOR CALCULATING ABSORPTION OF RADIO-FREQUENCY IN MODELS OF MAN AT AND ABOVE THE RESONANT FREQUENCY (MEETING ABSTRACT). (Eng.) Iskander, M. F.; Durney, C. H.; Barber, P. W.; Massoudi, H. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 45; 1977. (0 refs)

A technique to calculate absorption of radio frequency energy by a nonspherical model of man is described.

The technique is based on combining an anticipated solution with the extended-boundary-condition method (EBCM). By utilizing an improvement in the convergence of the solution, the size of the matrix is reduced, and the ill-conditioning encountered at and above resonance is avoided. The required initial approximation can be obtained either from asymptotic techniques (e.g., geometric optics, GO) or from any other anticipated solution. The solution for an infinite cylinder, which agreed well with the GO solution at higher frequencies and with experimental results at intermediate frequencies as the initial approximation was calculated. On the basis of this initial assumption, an integral equation in terms of the equivalent currents on the dielectric surface was derived and reduced to a system of matrix equations using the orthogonality relations. Although the main matrix resembled that obtained using the straight-forward EBCM, tests using two different methods revealed that by improving the convergence by about 20 to 30%, the ill condition of the matrix could be avoided. Numeric results for the averaged specific absorption rate for a nonspherical model of man at and above the resonance frequency are presented graphically and are compared with available experimental data. In the frequency range where no data were available for comparison, the off-center test of validity was employed to check the accuracy of the numeric procedure. Advantages of the method as well as other possibilities to improve its convergence for use at yet higher frequencies are discussed.

- 5367 **ABSORPTION CHARACTERISTICS OF A PROLATE SPHEROIDAL MODEL OF MAN AT AND NEAR RESONANT FREQUENCIES (MEETING ABSTRACT).** (Eng.) Lee, H.; Tripathi, V. K. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 46; 1977. (0 refs)

Analytic and numeric techniques were used to solve for absorption characteristics of a prolate spheroidal model of man that consisted of homogenous biologic tissues as irradiated by plane waves at an arbitrary angle of incidence at and near the resonant frequencies. The problem was formulated by expanding the internal and scattered fields in terms of spherical and spheroidal vector-wave functions. The internal fields were then calculated by applying the boundary conditions and utilizing suitable techniques for computations. In terms of the spherical wave functions, solutions were obtained by matching the boundary conditions and combining the point-matching technique with a least-square fit for better accuracy. The accuracy of the computations was verified by solutions that computed goodness-of-fit of boundary conditions but at points other than those used to obtain coefficients. In terms of the spheroidal wave functions, the numeric solutions were obtained either by the point-matching technique or by defining auxiliary spheroidal-angle functions that resulted in coupled simultaneous equations for the coefficients of expansion. Numeric results for the relative

absorption cross-section and for the internal distribution of absorption rates are presented for spheroids radiated by plane waves at and near resonant frequencies.

- 5368 **INDEXING ABSORPTION OF ELECTROMAGNETIC ENERGY BY BIOLOGICAL OBJECTS WITH PROLATE SPHEROIDAL MODELS (MEETING ABSTRACT).** (Eng.) Lin, J. C.; Wu, C-L. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 47; 1977. (0 refs)

Results are presented of computer calculations that made use of an expansion of the spheroidal wave function for wavelengths to and including the first resonant frequencies. The results may serve as a guide for extrapolating data from laboratory animals to human beings, particularly with regard to peaks and averages of absorbed electromagnetic energy.

- 5369 **APPLICATION OF IMPEDANCE-BOUNDARY CONDITIONS IN PROBLEMS OF MICROWAVE DOSIMETRY (MEETING ABSTRACT).** (Eng.) Taylor, L. S.; Dao, T. H. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 48; 1977. (0 refs)

The mathematical basis and validity of approximate impedance-boundary conditions in microwave dosimetry problems are briefly reviewed, and the technique of application is discussed. The use of the method is illustrated by comparing the results obtained from the approximations with those obtained from complete solutions of Maxwell's equations in several cases, including point and line sources irradiating lossy dielectric half-spaces and plane waves irradiating lossy dielectric spheres and cylinders at arbitrary angles and polarizations. These analyses are then employed to derive a number of rule-of-thumb conclusions with regard to the deposition of microwave energy in biologic systems via geometries in which no exact solutions are available. These conclusions are compared with the results obtained from thermographic measurements of microwave absorption by phantom loads.

- 5370 **GEOMETRICAL-OPTICS AND EXACT SOLUTIONS FOR INTERNAL FIELDS AND SARs IN A CYLINDRICAL MODEL OF MAN AS IRRADIATED BY AN ELECTROMAGNETIC PLANE WAVE (MEETING ABSTRACT).** (Eng.) Massoudi, H.; Durney, C. H.; Johnson, C. C. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 49; 1977. (0 refs)

A geometric-optics approximation was used to calculate the specific absorption rate (SAR) in cylindrical models of man and of experimental animals that were irradiated by an electromagnetic plane wave at high frequencies. Comparison of the results with those for prolate spheroidal models showed that the relative absorption cross section of the prolate spheroidal and cylindrical models of man are essentially the same at frequencies above 20 GHz. The exact solution is given for the SAR in a lossy, infinitely long cylinder that was exposed to an electromagnetic plane wave in which the vector of the E-field was either perpendicular or parallel to the cylinder's long axis. Curves are presented that show the SAR as a function of frequency for cylindrical models of man and of animals. Comparison is made with a composite curve that was calculated from data on prolate spheroids and from other experimental and theoretic data. The exact solution for the SAR of a cylindrical model of animals and humans appears to be a good approximation at a range of frequencies just below the limit of geometric optics, therefore providing a means for calculating SARs within a range of frequencies where calculations were not previously available.

- 5371 ENERGY ABSORPTION BY BIOLOGICAL MODELS: CALCULATIONS BASED ON GEOMETRICAL OPTICS (MEETING ABSTRACT). (Eng.) Rowlandson, C. I.; Barber, P. W. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 50; 1977. (0 refs)

A technique based on geometric optics was used to calculate absorption characteristics for a prolate spheroidal model. The results provided asymptotes to which data on absorption at lower frequencies could be related. In the geometric-optics formulation, the surface of the prolate spheroid was approximated by small planar subareas. Parallel and perpendicular components of the incident wave were determined for each subarea and a transmission coefficient was calculated for each component. The energy transmitted into each subarea was assumed to be completely absorbed due to the small skin depth of lossy biologic bodies at millimeter wavelengths. The total energy absorbed by the prolate spheroid was found by summing over all subareas. Extensive validity testing for spheres with a radius equal to the minimum radius of curvature of a man-sized prolate spheroid indicated that the technique is applicable for frequencies at and above 60 GHz. Computer-generated results for different angles of incidence indicated a reversal of the behavior seen at lower frequencies. The results also indicate a slight increase in rate of energy absorption with increasing frequency. The increase was attributed to the decrease in permittivity with increasing frequency, which effectively resulted in a better impedance match between the spheroid and the surrounding free space.

- 5372 SOME RECENT RESULTS ON DEPOSITION OF ELECTROMAGNETIC ENERGY IN ANIMALS AND IN MODELS OF MAN (MEETING ABSTRACT). (Eng.) Gandhi, O. P.; Hagmann, M. J. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 51; 1977. (0 refs)

Results on deposition of electromagnetic energy in animals and models of man are presented. Frequencies at which individual parts of the body, such as, the arms and the head are at resonance were identified. For the first (geometric) resonance of the head at 470 MHz, 4.5 times the averaged value for the rest of the body was measured which corresponded to an absorption cross-section 3.1 times the physical cross-section. The experimental values agreed with numeric calculations based on a realistic model of man. The frequency for maximal energy deposition in the arms was 150 MHz with an absorption cross-section 2.3 times the physical cross-section. For certain length-to-width ratios, the enhancement in energy deposition was 30-40% higher than that for reflectors of infinite dimensions. These supergain combinations can exist for all corner angles between reflectors. Enhanced specific absorption rates (SARs) due to proximity to other biologic bodies were observed for two resonant, subresonant, or suparesonant targets close to one another. It was found that antenna theory may be used accurately to predict SARs. For two targets separated by 0.65 to 0.7 λ , the highest SAR, which was 170% of the free space value, was experimentally observed for anesthetized rats and for models of man for the $\hat{E} \parallel \hat{L}$ orientation. Higher enhancements of the SAR by factors as large as 2.5 are anticipated for the interposed bodies of three or more targets.

- 5373 NUMERICAL CALCULATIONS OF ELECTROMAGNETIC ENERGY DEPOSITION IN A REALISTIC MODEL OF MAN (MEETING ABSTRACT). (Eng.) Hagman, M. J.; Gandhi, O. P.; Durney, C. H. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 55; 1977. (0 refs)

A realistic model of man was obtained by using 180 cubical cells of various sizes for best-fit to the contour of the 50th percentile "standard man." Anatomic cross sections were used to determine the volume fraction of eleven types of tissue in each cell. Published properties of the tissues were used to calculate the volume-weighted complex permittivity of each cell. A moment-method solution of the electric-field integral equation with a pulse-function basis and delta functions were used for testing. Numeric solutions previously reported had a ratio of 239:1 for energy deposition in one pair

of adjacent cells at 10 MHz. The arrangement of cells in the present model caused the maximum ratio of energy deposition in a pair of adjacent cells to be 8:1 at the same frequency. Reduced cell-to-cell variation improved the accuracy of the pulse-function approximation. Accuracy was further improved by using a three-dimensional interpolation with the \vec{E} values initially calculated for each cell to account for some of the variation of \vec{E} within each cell. The interpolated value was integrated in calculating the specific absorption rate (SAR). Calculations using the model with the homogeneous approximation of two-thirds the complex permittivity of muscle gave SAR values within 20% of values calculated for prolate spheroid and ellipsoid models. Unlike earlier numeric models, the distribution of energy deposition agreed well with that found experimentally for homogeneous phantom models. When the inhomogeneous complex permittivities were used with the model, a change of less than 2% occurred in SAR, but the distribution of energy deposition was changed. Figures showing the calculated distribution of SARs in the model are presented.

- 5374 NUMERICAL CALCULATION OF ELECTROMAGNETIC ENERGY DEPOSITION IN MODELS OF MAN WITH GROUNDING- AND REFLECTOR-EFFECTS (MEETING ABSTRACT). (Eng.) Hagman, M. J.; Gandhi, O. P.; Durney, C. H. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 56; 1977. (0 refs)

Image theory was applied to calculate rates of deposition of electromagnetic energy in a realistic model of man in the presence of a ground or reflectors. The ground plane or reflectors had perfect conductivity and infinite extent. Moment-method solutions were found for the electric-field integral equation using a pulse function basis and delta functions for testing. The resonant frequency of man standing on a ground plane was one-half that of man in a free field. The specific absorption rate (SAR) of man on the ground plane at the reduced resonant frequency was within 2% of the SAR for man in free space at the free-field resonant frequency. At 10 MHz, the SAR for man standing on a ground plane was about seven times that found for the same model in the free field. The factor of enhancement in local energy deposition due to grounding varied throughout the model and had a maximum of about 60 in the area of the heel. Experimental results with phantom models and numeric calculations revealed the SAR at different frequencies at various separations from the ground plane. At 65 MHz the computed SAR was 4.87 times the free-field value when man was 0.1875 wavelengths in front of a flat reflector and 16.6 times the free-field value when man was 1.5 wavelengths in front of the axis of a 90° corner reflector. Antenna theory was used to calculate the ratio of effective area of a half-wave dipole with a reflector to that of the dipole in the free field.

Such ratios were typically within 16% of the calculated values of enhancement of SAR due to reflector effects if man was near the resonant frequency. Numeric results for man at frequencies above resonance also are presented.

- 5375 INDUCED EM FIELDS IN HUMAN BODIES AND HEADS (MEETING ABSTRACT). (Eng.) Chen, K.-M.; Mousavinejad, H.; Rukspolmuang, S.; Nyquist, D. P. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 57; 1977. (0 refs)

The internal electric field and the specific absorption rate (SAR) of electromagnetic (EM) energy as induced by EM waves up to 500 MHz in a realistic model of man were theoretically quantified based on the numeric solution of a tensor integral equation. Theoretic results were compared with existing experimental results and with a measured electric field in a scale model as determined by an insulated electric-field probe. The internal electric field and the SAR induced by microwaves in a model of the human head, which included the eyes and the brain, also were quantified. The SARs in the eyes and in the brain were found to be lower than that in the surrounding bony structure at the microwave range. The accuracy of numeric results was checked with Stratton's exact solutions of irradiated homogeneous dielectric spheres.

- 5376 FAR-FIELD MICROWAVE DOSIMETRIC MEASUREMENTS IN A MAN-SIZE PHANTOM (MEETING ABSTRACT). (Eng.) Olsen, R. G. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 60; 1977. (0 refs)

Measurements of microwave heating were made in a full-size, upright model of the human being. The model, encased in and supported by a two-part mold of polyurethane, was composed of simulated muscle and bone. The phantom muscle was composed of a gelling agent, NaCl, polyethylene powder, and water. The major bones of the body were simulated by resin-based molded replicas of human bones. The phantom was placed in the far-field of a standard gain horn inside an anechoic chamber. Initial irradiations were in the L-band (1.29 GHz); the source of pulsed microwave energy was a military radar unit (AN/TPS-1G). The averaged power density of incident energy at the phantom and along the horn's axis was approximately 14 mW/cm². A small, nonmetallic temperature probe was inserted into the phantom at various locations and depths. During irradiation, the time course of temperature changes was recorded to provide for calculation of microwave dose-rate at the probe's location. Irradiations of 10 min or less produced elevations that were less than one-

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half a Celsius degree. Initial results revealed a predominant heating of the front surface with an uneven pattern. Microwave heating occurred at depths to 6 cm, but most of the incident energy was deposited within the first 2 cm of the phantom's frontal surface.

- 5377 DEVELOPMENT AND USE OF A CALORIMETER TO MEASURE SPECIFIC ABSORPTION RATES IN SMALL LABORATORY ANIMALS (MEETING ABSTRACT). (Eng.) Allen, S. J.; Hurt, W. D. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by the International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 61; 1977. (0 refs)

Two types of multiple-cell calorimetric systems were constructed—one for mice and one for rats—to measure specific absorption rates (SAR) in small laboratory animals. Thermistors were used to monitor a calorimeter's temperature. The current passed by thermistors was read out through a Monitor Labs Model-1200 scanner using a Data Precision Model-3500 digital multimeter with a BCD output fed into an H.P. Model 9830A computer. The system was small, relatively inexpensive and provided automatic calibration of thermistors, precise measurement of temperature, and a printout of whole-body SAR of each animal. Design and construction of the six-well calorimetric system is discussed. Experimental data obtained from irradiation of mice by 2.6-GHz fields in an 18-animal array are compared with those obtained from E-field measurements using the NBS-Model EDM-1B probe.

- 5378 ABSORPTION OF ELECTROMAGNETIC ENERGY BY PHANTOM MUSCLE-SPHERES AND BY BIRDS OF DIFFERING SIZE (MEETING ABSTRACT). (Eng.) Chou, C. K.; Guy, A. W. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 62; 1977. (0 refs)

Phantom muscle spheres (diameters 4, 6, 8, 12, and 16 cm) and birds (parakeets, quails, pigeons, chicken, turkeys) were exposed to far-field plane waves at power densities between 200 and 500 mW/cm² at 775, 915, and 2,450 MHz. Patterns of specific absorption rate (SAR) were determined by thermographic techniques for spheres and birds. Behavioral responses of birds were monitored. The SAR patterns in spheres were in good agreement with theoretic predications, while those of birds differed from those of spheres. Absorption in regions of the head and neck was much larger than in other parts of the body. The analogy of a bird to a sphere was not a good approximation, since objects shaped like birds and not those of simple geometry are needed for study of absorption. Behavioral response of birds to radiation varied. Threshold energy was determined for each bird at all three frequencies.

The lowest power density at which radiation was detected by a rooster was 7 mW/cm² at 775 MHz.

- 5379 THE NUMBER AND SPACING OF ANIMALS SIMULTANEOUSLY EXPOSED TO MICROWAVES IN A FREE FIELD AFFECT THE DOSE RATE (MEETING ABSTRACT). (Eng.) Kinn, J. B. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 63; 1977. (0 refs)

Whole-body absorption of energy was measured in mice and rats exposed either to 2,450-MHz or to 425-MHz radiation. Dosimetric measurements were made with twin-well calorimeters on mice exposed to 2,450-MHz radiation in an anechoic chamber. Specific absorption rates (SARs) for rats exposed to 425-MHz fields in a (transverse electromagnetic mode transmission line (Crawford cell)) were determined by power meters and by calculating the differences between forward, reflected, and transmitted power over intervals of time. For the 2,450-MHz exposures, mice were located in rectangular arrays of either 4, 9, or 25 animals with the separation-distance between animals halved for each increase in number of animal. The averaged SAR values for the different arrays were then compared. A positional dependence of dose rate was found to exist in the 25-mouse array. Rats were exposed in the Crawford cell to 425-MHz radiation with the number of animals increasing from 2 to 12 as separation-distance decreased. No relationship between separation-distance and averaged SAR for the 425-MHz exposures was found. It is concluded that the spacing between animals can affect SARs as can the position of an animal in the array.

- 5380 DEVELOPMENTAL EFFECTS OF MICROWAVES IN *TENEbrio MOLITOR*: EXPERIMENTS TO DETECT POSSIBLE INFLUENCES OF RADIATION FREQUENCY AND OF CULTURING PROTOCOLS (MEETING ABSTRACT). (Eng.) Pickard, W. F.; Olsen, R. G. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 66; 1977. (0 refs)

Pupae of the darkling beetle, *Tenebrio molitor*, were exposed to microwaves in the far-field of a horn-irradiated temperature-controlled electrically anechoic chamber. Exposed and control pupae were then allowed to develop into adults and were examined to determine whether the irradiation correlated with an increased incidence of gross morphologic abnormalities. Pupae were derived either from a colony maintained on ground Purina dairy meal and sliced potatoes (colony-pupae) or from larvae purchased in an advanced instar and maintained on Kellogg's Special-K and sliced potatoes (K-pupae). Control pupae from the colony developed into adults with a significantly lower incidence of developmental

abnormalities than did K-pupae controls. The following experiments were performed at 5.96 GHz. Pupae with the long axis of the body parallel to the electric field for 2 hr at 91 Vm^{-1} root mean square (rms) in a standing wave and at a nominal dose rate of 130 mW/g exhibited no effects in either population of pupae. Colony pupae parallel to the magnetic field for 2 hr at an H-field maximum of 1.53 A^{-1} rms in a standing wave distribution and at a nominal dose-rate of 54 mW/g, exhibited no effects, but a significant effect ($p = .034$) was observed in K-pupae. K-pupae parallel to the electric field of a traveling wave at 11 mW/cm² exhibited no effects after 13-hr exposure. Pupae antiparallel to the Poynting vector for 4 hr in a traveling wave (10.025 GHz at 5 mW/cm²) exhibited no effects.

- 5381 THE EFFECT OF MICROWAVE POWER LEVEL ON TERATOGENESIS IN *TENEbrio MOLITOR* (MEETING ABSTRACT). (Eng.) Green, D. R.; Rosenbaum, F. J.; Pickard, W. F. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 67; 1977. (0 refs)

Experimental results are presented that show the existence of a "power" window in which the teratogenic effect of microwaves on pupae of *Tenebrio molitor* is suppressed. Suppression in a waveguide occurred at power levels near 80 mW at 9.0 GHz. By segregating pupae into two groups based on their external appearance, it was shown that organisms weakened by prior trauma or by developmental abnormalities were more susceptible to microwave-induced damage than were those of healthier appearance. Evidence of nonlinear processes in the thermoregulatory behavior of *T. molitor* was found.

- 5382 THE INFLUENCE OF MICROWAVES ON DEVELOPMENT OF THE RAT (MEETING ABSTRACT). (Eng.) Michaelson, S. M.; Guillet, R.; Heggeness, F. W. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 68; 1977. (0 refs)

To investigate whether exposure of the developing rats to microwaves may influence maturation, female Long-Evans rats were exposed for 1 hr to 2,450-MHz continuous wave (CW) radiation at 10- or 40 mW/cm² power densities on various days of gestation. The dams were permitted to give birth, and the offspring were studied for functional development through the 21-day nursing period. In another study, neonatal rats were exposed at 40 mW/cm² to 2,450 MHz, CW radiation for 5 min each day from days 1 to 6 postpartum. On day 7, the rats either were sacrificed, were exposed to 2,450-MHz CW radiation for a seventh time, or were injected with adrenocorticotrophic hormone (ACTH). Among animals exposed in utero the

metabolic response to a cold environment was greater among offspring of rats exposed during days 0 to 2 than among the sham-exposed animals. The offspring from rats exposed at 40 mW/cm² showed a significantly higher level of corticosterone than sham-exposed controls during the first 24 hr of life. Thyroxin level tended to be lower among 1-wk-old rats from dams exposed at 10 mW/cm² but increased during the wk 2 of life. Among pups from dams exposed at 40 mW/cm², there was a statistically significant increase in thyroxin level at 14 and 16 days of age. Brain mass in offspring of dams exposed at 40 mW/cm² during day 13 or 20 of gestation did not differ from sham-exposed counterparts. Adrenal wet mass and ratios of adrenal-to-body mass in 7-day-old rats were significantly higher in radiated animals. Following either exposure to microwaves or injection of ACTH on day 7, plasma corticosterone levels were moderately increased in radiated animals. Whether exposure to microwaves during gestational or early neonatal periods perturbs or actually modifies ontogeny of neuroendocrine responsiveness requires further investigation.

- 5383 REPEATED EXPOSURE TO MICROWAVES AND ENVIRONMENTAL TEMPERATURE AFFECT BODY GROWTH OF NEONATAL RATS (MEETING ABSTRACT). (Eng.) Lu, S.; Pettit, S.; Michaelson, S. M. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 69; 1977. (0 refs)

The effects of repeat exposure to microwave and environmental temperature on the body growth of neonatal rats was investigated. Rats were exposed repeatedly to 2,450-MHz continuous wave radiation at 20 or 40 mW/cm² and at 24 C or at 24 and 34 C in the absence of radiation, 1 hr daily for 5 days during wk 1 or 2 of life. A highly sensitive period occurred during wk 1 of life in which rate of growth was easily perturbed. Repeat exposure to "cold" (24 C relative to a neutral temperature of 34 C) depressed body growth. Microwave radiation at 20 mW/cm² counteracted the depressive effects of the "cold" environment. Radiation at a higher power density (40 mW/cm²) accelerated growth. Although it is premature to judge whether acceleration of growth by microwave irradiation is beneficial in terms of early postnatal development, interaction between environmental temperature and early development is noteworthy.

- 5384 EFFECTS OF PRE-AND POST-NATAL EXPOSURES TO 918-MHz MICROWAVE RADIATION ON DEVELOPMENT AND BEHAVIOR IN RATS (MEETING ABSTRACT). (Eng.) Johnson, R. B.; Mizumori, S.; Myers, D. E.; Guy, A. W.; Lovely, R. H. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 70; 1977. (0 refs)

Rats were exposed to 918-MHz continuous wave circularly-polarized guided microwaves at averaged power densities of 5 mW/cm² in two separate studies to determine the effects of pre- and postnatal exposures on development and behavior. In the first study, rats were exposed daily for 7 days, 3 hr/day on days 2-9 of life. No statistical differences existed between test animals and control on measures of body mass through maturity, eye-opening dates, thermoregulatory-circadian rhythm, or conditioning of an active avoidance response. In the second study, rats were exposed in utero for a total of 380 hr. The exposure produced slight but consistent differences in body mass at birth and in eye-opening dates. The exposure may have accelerated in utero development. Assessment of thermoregulatory capacity as well as active avoidance of adults revealed possible long-term developmental differences.

5385 EMBRYOTROPIC EFFECTS OF PULSED ELECTRO-
STATIC FIELDS (MEETING ABSTRACT). (Eng.)

Pafkova, H. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 71; 1977. (0 refs)

The effect of chronic electrostatic irradiation applied from days 1-17 of gestation was studied in mice. The structure of placentas and fetal sacks, the occurrence of resorptions, the number and structural integrity of dead fetuses, and the mass and structural integrity of mature infants were evaluated. Significant changes were observed in exposed materials indicating that a pulsed electrostatic field has an unfavorable influence on embryonic development, especially during earlier stages. The influence of pulsed electrostatic fields of differing repetition frequency and field-gradient on the development of the chicken embryo was also studied. As applied once during an early state of development, the field did not influence the vitality of embryos and had no teratogenic effects. However, the body mass of the exposed embryos was significantly lower than that of controls.

5386 EFFECTS OF CHRONIC EXPOSURE TO MICROWAVES
AT LOW POWER DENSITIES ON THE MASS AND
CRANIAL SIZE OF DEVELOPING CHICKEN EMBRYOS (MEETING
ABSTRACT). (Eng.) Fisher, P.; Lauber, J. K.; Voss,
W. A. G. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 72; 1977. (0 refs)

The effects of chronic, low power density microwave exposure on the mass and cranial size of developing chicken embryos were studied. Fertile eggs from an outbred flock of *Gallus gallus* were incubated in groups of 36 for 4 days in a Plexiglas and Styrofoam incubator. The incubator was located within

an electrically anechoic chamber (27 dB return loss) and was connected to a remote custom-built environmental control unit. The eggs were irradiated in the far field, 1.68 m from a standard gain horn (10.2 x 12.4 cm) at a mean power density near 3.3 mW/cm². Power densities within the incubator varied between 1.4 and 6.2 mW/cm². At the end of each period of incubation, embryonic temperature was rapidly measured, in ovo, with a microthermocouple. The embryos were subsequently excised, measured for mass, and photographed. Nose-to-crown length was recorded, as an index of cranial size from a photographic enlargement. Radiation was found in most cases to affect significantly the mass and cranial size of 4- and 5-day embryos. The direction of the observed effects appeared to be temperature dependent. At an incubation temperature of 33.5 C, values were significantly higher ($P < .01$) except for day-5 masses, while at 35.1 C all values were significantly lower ($P < .05$) as compared with controls. Since either temperature is considerably below the optimum for incubation, the finding of smaller mass and size of cranium may indicate an adverse athermal effect of microwave irradiation at low power densities.

5387 PRELIMINARY STUDIES OF ELECTRIC AND MAGNETIC
FIELDS AT 27 MHZ: FIELD SURVEYS AND RES-
PONSE OF BLOOD CELLS (MEETING ABSTRACT). (Eng.)

Mild, K. H. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 77; 1977. (0 refs)

Human red blood cells were exposed for 3 hr in 27-MHz fields at strengths as high as 3,000 V/m. Leakage of potassium ions (K⁺) from exposed cells did not differ from that of control cells maintained at the same temperature. In cells tested for changes of osmotic resistance that might result from a change in the amount of bound water, no difference was observed between exposed and control cells.

5388 QUANTITATIVE DETERMINATION OF THRESHOLD
VALUES OF MAGNETOPHOSPHENES (MEETING ABS-
TRACT). (Eng.) Loevsund, P.; Oevberg, P. A.;

Nilsson, S. E. G. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 81; 1977. (0 refs)

To determine whether phosphenes (visual images) originate in the retina, threshold values of magnetophosphenes were quantitatively assessed in normal and color-blind human subjects under differing conditions of background illumination and dark adaptation. In production of phosphenes, the threshold of magnetic flux density was lowest near 20 Hz and was just above 10 mteslas at an ambient luminous intensity of 1.2 candelas/m². Thresholds differed in color-blind subjects. Some subjects

experienced after-images that persisted up to 30 min. Thresholds rose across time in the dark-sensitized eye. The data indicate that the retina is the site of generation of magnetophosphenes.

- 5389 THE EFFECT OF ELF ELECTRIC FIELDS ON HUMAN REACTION TIME AND CRITICAL FLICKER FREQUENCY (MEETING ABSTRACT). (Eng.) Sugiyama, S.; Mizuno, K. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 82; 1977. (0 refs)

Simple reaction time (motor response to a photic stimulus) and critical flicker frequency (CFF) were studied in five young men and women. Measures were recorded both in the absence and in the presence of a 20-Hz electric field that was applied by a conductive plate 20 cm above the subject's head. Three root mean square kV were applied to the overhead plate. The difference between means of reaction times (control = 250.7 msec; under exposure = 242.4 msec) was small but reliable ($p < .05$). Similar alterations of CFF were noted. It is concluded that the electric field is capable of influencing the central nervous system.

- 5390 SOME PECULIARITIES OF THE AUDITORY SENSATION EVOKED BY PULSED ELECTROMAGNETIC RADIATION (MEETING ABSTRACT). (Eng.) Tyazhelov, V. V.; Tigranian, R. E.; Khizhnyak, E. P.; Akoev, I. G. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 83; 1977. (0 refs)

Auditory sensations evoked by pulsed microwaves were investigated while observers' heads were irradiated at a frequency of 800 MHz and a power density not exceeding 2,000 mW/cm². The pulse repetition rate (PRR) was 0-10,000/sec and the pulse width (PW) was 5-30 μ sec. The threshold of peak power in production of an auditory sensation was essentially flat from 1 to a value that ranged from 500 to 1,000 PPS. The threshold then rose and reached cut-off between 8,000 and 10,000 PPS. Attempts to produce a beat-frequency response in the observers through combined stimulation with microwaves and an auditory stimulus were successful but only when the latter exceeded 8 KHz. When observers slowly submerged their heads in water, they could still "hear" the microwaves but with diminishing loudness until the head was fully submerged. In other studies, a rise in the hearing threshold was noted when PWs were increasing toward 100 to 120 μ sec. Observers reported that auditory sensations induced at these longer PWs had a lower pitch and appeared to originate from a different point in space. While thresholds were higher at longer PWs, some observers who were "deaf" to the "usual" shorter pulses were able to "hear" the

microwaves. It is concluded that current models of radio frequency hearing will require further development.

- 5391 QUANTITATION OF EFFECTS OF CHRONIC MICROWAVE RADIATION ON MUSCLE CELL OSMOTIC STATE AND SELECTIVE MEMBRANE PERMEABILITY (MEETING ABSTRACT). (Eng.) Portela, A.; Guardado, M. I.; de Xammar Oro, J. R.; Brennan, M.; Trainotti, V.; Stewart, P. A.; Perez, R.; Rodriguez, C.; Gimeno, A.; Rozzell, T. C. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 84; 1977. (0 refs)

To investigate the effects of chronic microwave radiation on muscle cell osmotic state and selective membrane permeability, frogs were maintained under constant environmental conditions and subjected daily to irradiation by pulsed microwaves (10.41 cm wavelength) at a power density of 10 mW/cm² for 0.1 hr for 20, 40, 60, 80, or 100 days. At the end of each of these periods, frogs were sampled and dissected. Tibialis anticus muscles were cut in pairs from each frog and single-muscle fibers were isolated. Control and irradiated frogs were analyzed for: (a) change of cell volume as a response to an osmotic gradient: fraction of osmotically available cell water (Weff), cell-water permeability (Pw), and consequently, the cellular osmotic state; (b) cell membrane "mechanical resistance" and selective permeability to solute and solvent [$V = f(t)$], initial rate of cell-volume change as a function of isosmolar concentration of probing molecules (dV/dt at $t = 0$) and Ciso, the concentration of probing molecules (dV/dt = 0 at $t = 0$); the Staverman reflection coefficients (σ) and the membrane-equivalent pore radius (r in A); and (c) the maintenance of normal cell volume (V_{d0}), inferred from the normal distribution of cell Na⁺, K⁺, Cl⁻ and water contents by normal activity of the Na-K pump. No changes were detected in any of these cellular parameters. Results indicate no muscle-cell cumulative effects for microwave exposure.

- 5392 IMMUNOLOGICAL AND HEMATOLOGICAL EFFECTS OF MICROWAVES AT LOW POWER DENSITIES (MEETING ABSTRACT). (Eng.) Shandala, M. G.; Rudnev, M. I.; Vinogradov, G. K.; Belonozhiko, N. G.; Gonchar, N. M. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 85; 1977. (0 refs)

Rats were intermittently exposed to ultra-high-frequency (UHF) energy for 30 days at power densities of 10, 50, or 500 μ W/cm² to investigate the immunologic and hematologic effects of microwave irradiation at low power densities. Assays of blastic transformation of lymphocytes in conjunction with mito-

genic stimulation were performed on days 3, 7, 10, 14, 21, and 30 days. Exposures at 50 $\mu\text{W}/\text{cm}^2$ were associated with a downward trend in relative numbers of transformed T-cell lymphocytes. Exposures at 50 and 10 $\mu\text{W}/\text{cm}^2$ were associated with an initial augmentation of transformation that was followed by a reduction below control values. Rats were also observed for content of glycogen (G) and of alkaline phosphatase (AP) in neutrophils of peripheral blood. Increases of G and AP were observed during day 3 in animals exposed to 10 and 50 $\mu\text{W}/\text{cm}^2$, after which the values oscillated below and above control values. At 500 $\mu\text{W}/\text{cm}^2$, the content of G was substantially lower during the entire 30-day period; values of AP rose until day 7 and then exhibited the oscillation noted at lower power densities. Autoallergenic activity was observed at 500 $\mu\text{W}/\text{cm}^2$; specifically, antibodies of brain and liver were detected in rats, guinea pigs, and rabbits after exposure to UHF fields. It is concluded that exposure to UHF fields can induce a primary lesion in the immunologic system and can also result in autoimmune disease.

- 5393 PRELIMINARY RESULTS ON THE EFFECTS OF MICROWAVES ON THE RETICULO-HISTIOCYTIC SYSTEM (MEETING ABSTRACT). (Eng.) Miro, L.; Senelar, R.; Draussin, M.; Grasset, C.; Mion, H.; Coste, J. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 86; 1977. (0 refs)

To investigate the effects of microwave radiation on the reticulo-histiocytic system, 16 rabbits and 5 guinea pigs were exposed to 3.1-GHz microwaves for a total of 320 hr. The pulse repetition rate was 500/sec and the pulse width, 1 μsec . The experiment was carried out in an anechoic chamber at an averaged power density of $1.2 \pm 0.2 \text{ mW}/\text{cm}^2$. Six rabbits and three guinea pigs served as controls. During sham radiation and radiation treatments, no differences in behavior of control and exposed animals were noted. Necropsy of brain, kidney, suprarenal glands, and liver revealed no thermal disturbance. Metabolic assays of reticulocytes revealed a lower colloidal hematocrit in exposed animals than in controls ($p < .05$), and uptake of colloidal ^{198}Au by Kupfer hepatic cells was slower in exposed animals ($p < .05$). The mitotic activity of spleen, thymus, and lymph node cells was significantly higher in exposed animals, and these organs also exhibited greater infiltration by lymphocytes. Titers of gamma globulin were increased significantly 8 days after exposure to microwave irradiation. The data indicate that prolonged irradiation of the mammal by pulsed microwaves at $1.2 \text{ mW}/\text{cm}^2$ results in augmented metabolism of reticulocytes and an increased presence of circulating components of the immunologic system.

- 5394 EFFECTS OF MICROWAVE EXPOSURE ON IMMUNOCOMPETENT CELLS (MEETING ABSTRACT). (Eng.) Czerski, P.; Wiktor-Jedrzejczak, W. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 87; 1977. (0 refs)

The effects of microwave exposure on immunocompetent cells are reviewed. Microwave-induced depression of phagocytic activity of macrophages and granulocytes has been reported. Impaired release of granulocytes and ability of irradiated animals to combat bacterial infections also have been described. A dramatic improvement in survival of mice infected with herpes viruses has been reported, with the effect dependent on schedule of irradiation. An increased production of protein in the cells of the reticuloendothelial system (thymus, spleen, and liver) of mice exposed to microwaves has been described. Single or repeated exposures of mice have led to an increase in vivo in the percentage of Ig^+ , Ig^+CR^+ , and plaque-forming cells among splenic lymphoid cells. Changes in the kinetics of immunoglobulin M production in irradiated mice have been demonstrated; the direction of the change is highly dependent on schedule of irradiation. Transient peripheral lymphocytosis has been seen in many species following irradiation. That in vivo maturation and function of lymphocytes are dependent on energy dose and schedule of irradiation is well documented. However, it is not known whether these effects are mediated or direct cellular effects. The answer may lie in the observation that microwave-induced lymphoblastoid transformation in vitro occurs and that lymphoid cells exposed to microwaves in vitro respond normally to T- and B-cell mitogens.

- 5395 PATTERNS OF CHANGE IN BEHAVIORAL REACTIONS TO LOW POWER DENSITIES OF MICROWAVES (MEETING ABSTRACT). (Eng.) Shandala, M. G.; Rudnev, M. I.; Navakatian, M. A. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 88; 1977. (0 refs)

Randomly bred albino rats were exposed to 2,375-MHz microwave radiation at power densities of 10 or 50 $\mu\text{W}/\text{cm}^2$, 7 hr/day, for 90 days to assess changes in behavioral reactions. Behavioral measures involving a photically-and sonically-cued avoidance reaction, open-field exploratory activity, and threshold of electric shock to the feet, were obtained on days 10, 20, 30, 60, and 90 of exposure. After 10 days, acquisition of the aversive habit by exposed rats was more rapid (mean number of trials at 10 $\mu\text{W}/\text{cm}^2 = 14.2$, and at 50 $\mu\text{W}/\text{cm}^2 = 18.0$) than that by controls (mean number of trials = 24.2). The differences between exposed groups and controls were reliable

(both $p < .05$). After 20 days the differences were negligible and by day 90 they were reliably reversed (mean number of trials by controls = 17.3; respective means at 10 and 50 $\mu\text{W}/\text{cm}^2$ = 35.2 and 55.7 trials; all three means differed at $p < .05$). Activity of the three groups in the open-field apparatus differed little on day 10 but was significantly depressed by day 90 in both exposed groups. Thresholds of behavioral reaction to electrical shock were lower in exposed rats on day 10 but eventually rose and were higher on day 90. The data indicate the existence of phase-dependent changes in several behavioral endpoints in rats repeatedly exposed at 10 and 50 $\mu\text{W}/\text{cm}^2$; an initial phase of central nervous excitation is subsequently followed by inhibition.

- 5396 QUANTUM MECHANICAL APPROACHES TO THE MECHANISM OF INTERACTION OF MICROWAVES WITH LIVING SYSTEM (MEETING ABSTRACT). (Eng.) Czerski, P.; Achimowicz, J. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 3, 1977: pp. 89; 1977. (0 refs)

The effects of microwave radiation on the nervous system, the immunocompetent and blood-forming cell systems, and on cell division, cell membrane, chromosomes and bacteria are reviewed and explained in terms of quantum mechanical theory. A generally applicable explanation is based on the Frohlich phenomenon of long-term energy storage in macromolecules and the emerging theory of collective phenomena, as developed by Frohlich, Cope, and others. Superconductivity in biologic systems and multiphoton activation are also considered. Approaches to experimental verification of proposed theory are discussed.

- 5397 THRESHOLD ENERGY FOR HEARING MICROWAVE PULSES OF 10- TO 500- μs DURATION (MEETING ABSTRACT). (Eng.) Chou, C. K.; Guy, A. W. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 92; 1977. (0 refs)

Evoked responses from the brainstem were recorded from guinea pigs to study the threshold of microwave hearing. Microwaves (generated by a klystron) at 918 MHz with a pulse-width between 10 and 500 μsec were fed into a cylindrical waveguide that was used to radiate the guinea pig's head. For pulses $< 30 \mu\text{sec}$, the threshold was independent of the absorbed energy per pulse. As the pulse-width increased, the energy required to reach threshold also increased. For pulses $> 70 \mu\text{sec}$ the threshold was independent of the peak power density. The dependence of the threshold energy of the hearing effect on the microwave pulse-width agreed well with the prediction of the thermal-expansion theory.

- 5398 MIDDLE-EAR IMPAIRMENT AND MICROWAVE HEARING (MEETING ABSTRACT). (Eng.) Chou, C. K.; Galambos, R. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 93; 1977. (0 refs)

Amplitude and latency of maximum brainstem evoked responses (BERs), as recorded from guinea pigs, were obtained for acoustic and microwave stimuli under various stimulus intensities. The effects of external-ear blocking, middle-ear damping, and middle-ear destruction on the BER were studied. Results show that only when the inner ear (cochlea) is intact is the animal capable of hearing pulsed microwaves.

- 5399 EIGHTH-NERVE DERIVED, SINGLE-NEURON RESPONSES TO ACUTE MICROWAVE RADIATION OF THE HEAD (MEETING ABSTRACT). (Eng.) Lebovitz, R. M.; Seaman, R. L. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 94; 1977. (0 refs)

The influence of pulse-modulated (PM) and continuous wave (CW) microwave radiation (MWR) on eighth-nerve-related afferent systems was studied during acute exposures of cats. MWR at 915 MHz was applied to the head via a diathermy-type plane-wave applicator, while activity of a single neuron was recorded via glass micropipettes filled with 2 M NaCl. The responses of single auditory units to PM-MWR and to traditional acoustic stimuli were compared with respect to response threshold, response latency, and form of the probability distribution of post-stimulus firing times. In general, the responses to acoustic "click" stimuli and to PM-MWR were similar, differing only in amplitude. The PM-MWR influence on single auditory units appeared to originate from a mechanical interaction with portions of the auditory apparatus peripheral to the basilar membrane. However, the threshold of averaged microwave dose rate was several orders of magnitude below the current thermal-safety standard. Pulsed, not averaged, parameters of MWR appeared to be more significant in determining the nature of the response. From these data an estimate of the relative efficiency and mechanical nature of the PM-MWR effects could also be derived, establishing the basis for a novel communications channel. Similar comparisons of the responses of vestibular single units to CW-MWR and to traditional vestibular stimulation were performed. A MWR-mediated stimulation of cells innervating the semicircular canals, which was consistent with the hypothesis of a microwave-induced caloric vestibular stimulation was demonstrated. The threshold for vestibular activation via CW-MWR exceeded the dose rate at which thermal effects would be expected in the head of the test animal. However, the basis for a new method for

clinical diagnosis of labyrinthine functioning was established. A major improvement in the coupling efficiency of this interaction could be achieved by appropriate selection of geometric and radiation parameters (such as frequency and/or modulation characteristics). A significant finding is that reliable spike-train (firing-time) data can be obtained coincident with exposure to MWR.

5400 THE EFFECT OF MICROWAVES ON CRAYFISH
NEURONS (MEETING ABSTRACT). (Eng.)

Matsumoto, G.; Yamaura, I. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 95; 1977. (0 refs)

The effects of microwaves on the neuro-impulse frequency were studied in spontaneously discharging neurons in isolated abdominal ganglia and in the slowly adapting stretch-receptor neuron of the American fresh water crayfish. A few seconds of microwave irradiation (11 GHz) of the abdominal ganglia decreased acutely the spontaneous discharge frequency, which was nearly constant (within 20 impulses/sec) in the normal steady-state. The effect was observed when tissue temperature was elevated by microwave radiation more than 0.5 C; with smaller temperature changes, the effect was seldom detected. The pattern of the neuronal response to microwave radiation was characterized by inhibitory-on and excitatory-off responses, which were commonly observed in the nervous system. Simulation of the neuron's behavior indicates that the response pattern is composed of the superimposing of two responses. The results compare well with the static and dynamic characteristics of thermal stimulation of *Aplysia* neurons. The detailed sequential relationship between changes of tissue temperature and impulse frequency was clearly revealed when microwaves at 2.45 GHz were modulated by M-sequential signals. The results indicate that the impulse frequency of the crayfish neuron is a function of the temperature change of the tissue.

5401 MICROWAVE EFFECTS OF NERVE VITALITY
(MEETING ABSTRACT). (Eng.) McRee, D. I.

In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 96; 1977. (0 refs)

To study the effects of microwaves on nerve vitality, paired sciatic nerves from large specimens of *Rana pipiens* were exposed in a waveguide system. The exposed nerve crossed the waveguide near (within 2 mm) the proximal (to the microwave source) surface of the surrounding Ringer's solution; whereas, the control nerve was positioned 5-cm distal to the surface and was essentially unexposed. Applying

a maximum incident continuous wave power (at 2,450 GHz) of 1 W or less led to very slow rises of temperature (~ 2 C/hr), which registered almost equally (within 0.1 C) at corresponding points on each nerve. Both nerves were stimulated with twin pulses (separated by a 5-msec interval) at a repetition rate of 50 pulses per sec to elicit a maximal (Group A) compound action potential (CAP), followed (at the outset) by a CAP of about half-maximal size. During 1- to 4-hr of exposure periods, the nerve was first observed to undergo a prolongation of its refractory period and, later on, severe decreases in the maximal CAP size. During the same periods the control nerve showed little change in these characteristics. The microwave-specific effects appear to be due to an interference with neural regulatory mechanisms rather than a direct effect on the excitation process.

5402 THE VISUALLY-EVOKED ELECTROCORTICAL RESPONSE
OF THE GUINEA PIG AFTER MICROWAVE-INDUCED
HYPERTHERMIA (MEETING ABSTRACT). (Eng.) Bruce-
Wolfe, V.; Mathews, M.; Justesen, D. R. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 97; 1977. (0 refs)

Latencies of an early component (N_1) of the visually-evoked electrocortical response (VER) of four young guinea pigs were observed as a function of brain and rectal temperature. Descending series of measurements within a daily session (where rectal temperature was initially elevated to more than 42.5 C by 2,450-MHz energy at an averaged dose rate of 30-40 mW/g) yielded a number of single or multiple VERs as temperature fell across time. Ascending series across several daily sessions, where rectal temperatures were elevated above baselines in increments of 1 to 1.5 C per day, were also conducted. The previously reported curvilinear relationship between body temperature and latency of VER was verified in two of the animals during descending series. However, the function was consistently (and negatively) monotonic for all of the data based on ascending series, i.e., the shortest latencies were observed at 42.5 C. The implication is that nonlethal elevation of body temperature to a level between 42.5 and 43.0 C resulted in a reversible alteration of neuronal function, presumably of chemical origin. Comparisons of brain and rectal temperatures from baseline measures revealed that the former were consistently below the latter by as much as 2 C, but the difference narrows as temperature was increased by microwave radiation.

5403 EFFECTS OF UHF ENERGY ON THE CENTRAL
NERVOUS SYSTEM: DEMONSTRATION OF TRANSIENT
ELECTROENCEPHALOGRAPHIC (EEG) ABNORMALITIES IN RATS
(MEETING ABSTRACT). (Eng.) Klein, M. J.; Milhaud,
C. L. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science

& The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 98; 1977. (0 refs)

It was previously found that chronic exposure of rats to 2,450-MHz microwave radiation at a power density of 3-5 mW/cm² induced changes in cerebral electrogenesis that varied among individuals: 25% of irradiated subjects exhibited electroencephalographic (EEG) abnormalities, 30% showed questionable recordings, and 45% presented a normal EEG. To select sensitive subjects, i.e., those with disturbed electrogenesis after exposure, a special pharmacologic technique of electrobiologic signal detection was developed. In the first acute experimental run, the technique revealed a transient aspect of the previously described abnormalities. Initially, the EEG was questionable for 72% of the irradiated animals, 50% of which had abnormal EEGs between min 5-20 of experimentation. The latter percentage gradually decreased, and the EEG progressed toward normality. At min 50, only questionable EEG recordings persisted and in only 25% of the irradiated subjects. The results are discussed as a function of the possible effect of microwaves on cortical and subcortical structures. It is hypothesized that the transient paroxysmal elements that define abnormality are a sign of either functional disturbance or of other dysfunctions due to metabolic or toxic factors.

5404 MODELS OF LONG-RANGE ORDER IN CEREBRAL MACROMOLECULES: EFFECTS OF ELF, VHF AND UHF FIELDS IN CALCIUM BINDING (MEETING ABSTRACT). (Eng.) Bawin, S. M.; Sheppard, A. R.; Adey, W. R. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 100; 1977. (0 refs)

The effects of electromagnetic fields on the rate of calcium exchange between isolated chick or cat cerebral tissue were investigated. Previous studies indicated that the isolated tissue responds to stimulation by an extremely low frequency (ELF) field within a narrow-frequency band (6-20 Hz) and in an "amplitude window" (5-100 V/m). Amplitude modulation of a weak 147-MHz field (0.8 mW/cm²) also elicited a response but only in the same narrow, low-frequency modulation window (6-20 Hz). In a third series of experiments, the root mean square amplitude of a 450-MHz field that was modulated at 16 Hz varied from 0.1 to 5 mW/cm². Increased efflux of calcium occurred only at intensities between 0.1 and 1.0 mW/cm², defining an "amplitude window" in addition to that noted for ELF. It is hypothesized that membrane-surface charge-sites behave "coherently" over a considerable area and that a coherent patch may be triggered to change its state by a very weak trigger at a point. The triggering event may occur at the boundary between such a patch and a noncoherent surround.

5405 TWO PARAMETERS AFFECTING RADIATION-INDUCED CALCIUM EFFLUX FROM BRAIN TISSUE (MEETING ABSTRACT). (Eng.) Blackman, C. F.; Elder, J. A.; Weil, C. M.; Benane, S. G.; Eichinger, D. C. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 101; 1977. (0 refs)

An attempt was made to verify and extend the finding of changes in the binding of calcium to the surface of brain tissue during exposure to non-ionizing electromagnetic radiation. The cerebral cortex of newborn chicks, separated at the mid-line to provide a treatment/control pair, was labeled in vitro with radioactive calcium. The treated tissue was exposed in a Crawford chamber to 147-MHz radiation that was amplitude modulated at selected frequencies between 3 and 30 Hz at power densities between 0.5 and 2 mW/cm². Compared with nonirradiated controls, a statistically significant increase in calcium efflux ($p < .05$) was found when frequency of amplitude modulation was 16 Hz and averaged power density of radiation approximated 0.75 mW/cm². The data support the concept and location of the previously reported frequency "window" as well as power-density window in which calcium efflux is enhanced due to exposure to amplitude-modulated radiation.

5406 ACTIVITY OF MEMBRANE-BOUND ENZYMES EXPOSED TO AMPLITUDE-MODULATED 2450-MHZ RADIATION (MEETING ABSTRACT). (Eng.) Allis, J. W.; Fromme, M. L. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 102; 1977. (0 refs)

Membrane-bound enzyme systems were irradiated with amplitude modulated microwave radiation in a spectrophotometric apparatus where enzyme activity was measured during irradiation. The enzymes investigated were cytochrome oxidase, a key enzyme in the electron transport chain located in the inner membrane of mitochondria, and adenosine triphosphatase (ATPase) from red blood cell membrane, which is involved in maintaining the sodium-potassium balance of the cell. These enzyme systems were prepared from rat tissue and were subjected to 2,450-MHz radiation that was amplitude modulated at 16, 30, 90, and 120 Hz, which resulted in a specific absorption rate of 26 W/kg. Temperature was controlled at 25 ± 0.5 C for all experiments. Irradiations were begun immediately after initiation of the reaction and continued for several min, while the reaction rate was being monitored. Cytochrome oxidase activity was measured directly by monitoring the change in absorbance of its substrate, cytochrome c, at 550 nm. ATPase activity was measured using a coupled enzyme system in which the rate of conversion of ATP to adenosine diphosphate was followed at 340 nm by stoichiometric oxidation of nicotinamide adenine dinucleotide phosphate. Pyruvate kinase and lac-

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tate dehydrogenase performed the intermediate steps and were always present in excess so that the activity of ATPase was rate controlling. No statistical differences in enzyme activities were obtained between irradiated and control samples at any modulation frequency for either enzyme.

- 5407 EFFECTS OF MICROWAVE RADIATION ON ERYTHROCYTE MEMBRANES (MEETING ABSTRACT). (Eng.) Liu, L.-M.; Cleary, S. F. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 103; 1977. (0 refs)

Rabbit erythrocyte suspensions were irradiated at room temperature (23 C) with S-band microwaves in a waveguide irradiation chamber for 3 hr or less. The release of K⁺ ions, of hemoglobin, and the osmotic fragility of red cells were used to determine the effects of microwave irradiation on the erythrocyte's membrane. At 3.0 GHz and a power density at the center of the waveguide that was equivalent to a free field power density of 10 mW/cm², the maximum rise of temperature in the irradiated sample was 2.6 C during a 3-hr exposure. There was no difference in K⁺ flux, hemolysis, or osmotic fragility between the microwave irradiated sample and the conventionally heated sample, even though both were heated to the same temperature for the same duration. At an equivalent power density of 58 mW/cm², the maximum rise of temperature of the erythrocyte suspension was 15 C (i.e., from 23 to 38 C) and the percentage release of K⁺ ions from the irradiated samples was slightly higher than that from cells heated in a water-bath at the same temperature. The difference was not statistically significant at the 5% level as determined by a t-test. The same procedure was used to determine the effects of 2.45-GHz and 3.95-GHz microwaves. No apparent effect on permeability of the erythrocyte's membrane was found. Data from studies that involved shorter exposure times, higher power levels, ouabain-treated cells, erythrocytes of species other than the rabbit, and aged red cells also are reported.

- 5408 INJURY OF CELL MEMBRANES IN NORMAL AND SV₄₀-VIRUS TRANSFORMED FIBROBLASTS EXPOSED IN VITRO TO MICROWAVE (2450 MHZ) OR WATER-BATH HYPERTHERMIA (43°C) (MEETING ABSTRACT). (Eng.) Janiak, M.; Szmiglelski, S. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 104; 1977. (0 refs)

Mouse 3T3 fibroblasts and SV₄₀-virus transformed mouse-3T3 fibroblasts (SV-3T3) were heated in a water bath or by 2,450-MHz microwaves to 40 or to 43 C. At 15-30 min intervals during and after heating, permeability of cell membranes was evaluated. In other experiments the cells were heated for various periods of time (30-120 min); injury of cell

membranes and reversibility were evaluated at different times after exposure. Heating of cells to 43 C resulted in a rapid drop of ouabain-sensitive influx of 86-Rb, followed by decreased binding of ³H-ouabain. These phenomena were observed in SV-3T3 cells after 5-10 min of heating, while in normal 3T3 cells, 20-25 min was required to exert the same effect. The changes in active transport of potassium were fully reversible, but when heating was continued, the cell membrane was irreversibly damaged and became permeable to large molecules. Cells maintained at 40 C for 4 hr did not exhibit increased permeability to large molecules or increased release of ⁵¹Cr. No significant differences were observed in the sequence and time-course of cell-membrane injury between cells heated in a water bath and those heated in the microwave field. It is concluded that inhibition of active transport of potassium, the most early disturbance of metabolism found in cells heated to 43 C, plays a significant role in the mechanism of cell injury and inhibition of growth rate.

- 5409 A COMPARATIVE STUDY OF THE ACTION OF TWO TYPES OF MICROWAVE IRRADIATION ON LIPID METABOLISM IN MICE (MEETING ABSTRACT). (Eng.) Deficis, A.; Dumas, J. C.; Laurens, J.; Plurien, G. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 105; 1977. (0 refs)

It was previously established that continuous wave (CW) irradiation of the mouse in a cavity at frequencies between 2.35 and 2.50 GHz increases its level of serum triglycerides. The experiments were extended to the free-field condition where mice were exposed in an electrically anechoic chamber to 2.45-GHz CW microwaves. The same effect on serum triglycerides was observed. In this study, the effects of both modes of irradiation were studied using 2-mo-old male DBA mice; 60 animals were irradiated in cavities; 94 were irradiated in the anechoic chamber. Duration of exposure was 60 hr; 126 controls were used. Measured or extrapolated root mean square power densities ranged from 3-4 (± 3) mW/cm². Measurements of body temperature revealed no change between pre- and post-exposure readings. The levels of serum triglycerides of irradiated mice were significantly higher than those of controls, but the elevations were highest when irradiation took place in the free field. Levels of β -lipoproteins were correlated with those of the serum triglycerides.

- 5410 COMPARATIVE EFFECTS OF WATER BATH- AND MICROWAVE-INDUCED HYPERTHERMIA ON CELL SURVIVAL AND SISTER CHROMATID EXCHANGE (SCE) IN CHINESE HAMSTER OVARY (CHO) CELLS (MEETING ABSTRACT). (Eng.) Livingston, G. K.; Johnson, C. C.; Dethlefsen, L. A. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromag-*

netic Waves. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 106; 1977. (0 refs)

To investigate possible extrathermal effects of 2,450-MHz microwave radiation, the response of Chinese hamster ovary (CHO) cells to equivalent thermal insults in a microwave field and in a water bath was compared. Experimental and control suspensions of synchronous cells in the log phase of growth were maintained at 44 C for 10, 20, 30, 40, 50, or 60 min. The microwave treatment consisted of inserting a culture tube with the CHO cells into a waveguide—the longest dimension of the tube parallel to the E field—and applying sufficient energy to maintain the desired temperature. Temperature-rise profiles were matched by monitoring experimental and control suspensions with the liquid-crystal optic-fiber temperature probe. Colony assays that were performed 8 days after hyperthermal treatments showed no significant differences in survival of cells. The sister chromatid exchange (SCE) frequency was also measured after 20-min hyperthermal treatments. Temperature of microwave irradiated cells was monitored with a thermistor perpendicular to the E field and in contact with the cell's monolayer. Hyperthermia elevated the SCE frequency above the control value ($11.5 \pm 0.38/\text{cell}$) but there was no significant difference between cells treated in the water bath (17.3 ± 0.43) and in the microwave field (16.6 ± 0.69). No extrathermal effects of microwave radiation were detected in either of the experiments.

5411 EFFECTS OF MICROWAVES ON SPERMATOZOA AND OBSERVATION OF MOTILITY BY THE LASER-SCATTERING TECHNIQUE (MEETING ABSTRACT). (Eng.) Shimizu, H.; Sakurai, K.; Matsumoto, G. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 107; 1977. (0 refs)

The motility of spermatozoa of a sea chestnut (*Hemicentrotus pulcherrimus*) was studied after microwave irradiation by a laser light scattering technique. Two 6-ml samples of sperm from the same sea chestnut were prepared in test tubes. One sample was exposed to 2,450-MHz microwaves for 10 sec in a cavity; the temperature of the radiated sample was elevated by 5 C. The elevation of temperature of the control sample, which was heated by conventional means, was equivalent to that of the irradiated sample. Measurement of motility began immediately after heating and required about 1 min. The motility of sperm was essentially the same in both samples. The acute effect of microwaves on motility of spermatozoa appears to be due to thermal effects.

5412 FACIAL IRRADIATION OF THE FREELY RESPONDING *MACACA MULATTA* BY A 9.3-GHZ PULSED MICRO-

WAVES: A LONG-TERM INVESTIGATION (MEETING ABSTRACT). (Eng.) McAfee, R.; Gordon, R.; May, J.; Elder, S. T. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 110; 1977. (0 refs)

A long-term investigation of the cataractogenic effects of microwave irradiation is reported together with an attempt to replicate certain behavioral and physiologic effects of microwaves in freely responding rhesus monkeys. The treated group ($n = 24$) and the control group ($n = 75$) were maintained in family groups in outdoor cages along with their infants. The adults individually entered an irradiation chamber and depressed a glass drinking tube that activated a microwave generator, which irradiated the monkey's face and eyes by energy from a 15-dB gain horn at 15-cm distance. Closure of the drinking-tube switch also allowed delivery of apple juice through the tube on a variable ratio schedule of reinforcement. Some monkeys worked 10 min for juice reward, while others worked for 20 min. The monkeys will be irradiated 4 days/wk for 52 wk, with follow-up for at least 2 additional years. The radiation source is an AN-CPN-6 radar beacon that is operated at 9.3 GHz in pulsed mode (0.5 μsec) at an averaged power density between 150 and 495 mW/cm^2 . Power density is controlled by varying the pulse repetition frequency (i.e., 1,000 pulses/sec yields 150 mW/cm^2). Examinations of monkeys to date have revealed no evidence of deleterious ocular effects of the radiation after 40 sessions. Social behavior and the health and fecundity of the irradiated animals have not been altered. Behavioral changes, which might be reflected in rate of lever pressing, have not been apparent.

5413 HEMATOLOGIC AND SERUM-CHEMISTRY EVALUATION IN RATS EXPOSED TO 60-HZ ELECTRIC FIELDS (MEETING ABSTRACT). (Eng.) Ragan, H. A.; Pipes, M. J.; Kaune, W. T.; Phillips, R. D. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 126; 1977. (0 refs)

Hematologic and serum-chemistry evaluations were performed in twenty young adult female Sprague-Dawley rats exposed 21 hr daily for 15 or 30 days to a uniform, vertical 60-Hz electric field at an unperturbed field strength of 100 kV/m ($\pm 5\%$). An equal number of rats was sham-exposed under identical housing and handling conditions. A third group of rats was maintained in the laboratory and served as caged controls. Hematologic evaluations were made using venous blood obtained from unanesthetized rats. For measures of clinical chemistry, the rats were anesthetized with ether prior to collection of blood from the heart; aliquots of serum then removed and quick-frozen until assayed. No significant differences among the three treatment

groups were observed on any hematologic end-point including volume of packed red cells, red blood cell counts, hemoglobin concentrations, red cell corpuscular constants, reticulocyte concentrations, white blood cell counts, absolute distribution of leukocyte cell types, platelet concentrations, and bone marrow cellularity. No effects of electric field exposure were observed on the serum-chemistry endpoints including blood urea nitrogen, alkaline phosphatase, glutamic oxaloacetic transaminase, serum iron, total iron binding capacity, glucose-serum proteins, or the concentrations of albumin and the serum-globulin fractions as determined electrophoretically. The results of these studies using rigidly defined and controlled electric fields are compared with studies using much lower field strengths in which effects on hematologic and serum-chemistry variables have been reported.

- 5414 CHRONIC EXPOSURE OF PRIMATES TO ELF ELECTRIC AND MAGNETIC FIELDS (MEETING ABSTRACT). (Eng.) Grissett, J. D. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 127; 1977. (0 refs)

The physiologic and clinical effects of chronic exposure to electric and magnetic fields similar to those near the antenna of the U.S. Navy's proposed extremely low frequency (ELF) communications system were investigated. Body currents induced by this system were similar to those induced by some power distribution systems; therefore, the results of this experiment were of value in assessing the environmental impact of electric power technology. Thirty monkeys (*Macaca mulatta*) were exposed to a magnetic field of 0.2 milliteslas (mT), which is 10 times greater than the worst case conditions at the ELF antenna. The intensity of the electric field was 20 V/m, which is 2 times greater than that at the soil's surface near the grounding terminal and 300 times greater than that at the soil's surface along the antenna. Blood chemistry and metabolic data were collected at weekly intervals; comprehensive clinical examinations were given every 6 wk. Statistic analysis of the data was accomplished with a two-factor analysis of variance (ANOVA) with repeated measurements on one of the factors. The field-level factor contained exposure to the field and a non-exposed control. The analysis was designed to determine whether the experimental animals responded differently from controls across time and whether the overall data from one group differed from the other. The analyses are summarized and graphically presented with respect to data gathered after 22 mo of exposure.

- 5415 EFFECTS OF ELF FIELDS ON THE SLIME MOLD *PHYSARUM POLYCEPHALUM*: EVIDENCE FOR DEPRESSION OF CELLULAR FUNCTION AND FOR A TRANSFERABLE FACTOR (MEETING ABSTRACT). (Eng.) Greenebaum, B.; Goodman, E. M.; Marron, M. T. In: *Abstracts of 1977 International Symposium on the Biological*

Effects of Electromagnetic Waves. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 129; 1977. (0 refs)

The slime mold *Physarum polycephalum* was exposed to a variety of low level, extremely low frequency (ELF) fields for periods ranging from 2 mo-5 yr. Reproducible changes, significant at the $p < .05$ level were induced in several biologic parameters. Changes were generally about 10% in magnitude and consisted of a slowing of cellular processes: the cultures maintained their capacity to survive and reproduce. Cultures were exposed to 75-, 60-, and 45-Hz continuous wave (CW) and to 76-Hz MSK frequency-modulated fields at strengths ranging from 0.1 to 2.0×10^{-4} teslas (root mean square [rms]) and 0.04 to 0.7 V/m (rms). In most experiments both electric and magnetic fields were applied, but in some, only one or the other component was applied. Cultures were maintained in constant-temperature incubators that were equipped with identical magnetic field coils and other interior fittings. Growth vessels incorporated parallel plane stainless steel electrodes, which established the electric fields across the medium in which the slime mold was growing. In one experiment, however, all-glass vessels were used. Changes reported earlier during exposure of the mold to CW fields were again observed, including a lengthening of the cycle of mitotic nuclear division, lengthening of the period of spontaneous oscillatory streaming of the protoplasm and a decrease in respiration. The magnitude of effects and the rapidity of their onset were dependent on field intensity and frequency. Data are also presented from experiments in which cultures that combined *Physarum* from exposed and control cultures exhibited a mitotic cycle that was intermediate in length to that of the parent stocks. This was interpreted as evidence for some sort of transferable factor or deficit. Indirect measurements indicated that no apparent genetic differences were induced by exposure to ELF fields.

- 5416 BIOLOGICAL EFFECTS OF 60-HZ ELECTRIC FIELDS ON GROWTH AND METABOLIC STATUS OF RATS (MEETING ABSTRACT). (Eng.) Phillips, R. D.; Chandon, J. H.; Lang, L.; Hilton, D. I. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 130; 1977. (0 refs)

A comprehensive investigation of the possible biologic effects on small laboratory animals of exposure to 60-Hz electric fields is described. Systems have been built for chronic exposure of large numbers of rats and mice to uniform, vertical electric fields. A multidisciplinary research team is evaluating possible effects of electric-field exposure on hematology, serum chemistry, immunology, endocrinology, neurophysiology, central nervous system function and structure, pathology, cardiovascular function, bone growth and structure, reproduction, development, teratology, and growth.

In addition, the effects of electric field exposure on growth and metabolic status of rats are being assessed.

- 5417 ECG AND HEART-RATE RESPONSE OF RATS EXPOSED TO 60-HZ ELECTRIC FIELDS (MEETING ABSTRACT). (Eng.) Hilton, D. I.; Chandon, J. H.; Phillips, R. D. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 131; 1977. (0 refs)

Electrocardiograms (ECG) were recorded, and heart rates were determined for rats exposed to uniform 60-Hz electric fields at 80 kW/m. Heart rates and temporal characteristics of ECGs of rats exposed for 8 hr did not differ significantly from those of sham-exposed controls. Heart rate values of animals exposed for 40 hr (8 hr/day for 5 days) did not differ significantly from values obtained from controls.

- 5418 LONG TERM FOLLOW-UP MACACA MULATTA EXPOSED TO HIGH POWER LEVELS OF 15-, 20-, AND 26-MHZ RADIO-FREQUENCY RADIATION (MEETING ABSTRACT). (Eng.) Krupp, J. H. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 136; 1977. (0 refs)

The whole-body thermal response to radiation at high power densities (500-1,270 mW/cm²) of 15-, 20-, and 26-MHz radio frequency radiation was measured in two groups of monkeys (*Macaca mulatta*) that totalled 18 animals. Each animal was exposed for 6 hr on at least two occasions. One or two yr later, standard clinical pathologic techniques were used to measure various hematologic and biochemical parameters. Physical examinations were performed, including slit-lamp examinations of the lens of the eye and ophthalmoscopic examination of the fundus. No variations from normal values or conditions were found that could be attributed to the radiation.

- 5419 EFFECTS OF RADIO WAVES ON GROWTH, HEMATOLOGY AND HISTOLOGY OF MICE (MEETING ABSTRACT). (Eng.) Lin, J. C.; Nelson, J. C.; Ekstrom, M. E.; Nam, S. H. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 137; 1977. (0 refs)

The effects of single or repeated exposure to radio frequency (RF) energy on growth, hematology, and histopathology were investigated in male and female C3H mice. Animals were exposed at a power density

of 1 mW/cm² in a rectangular exposure chamber at 148 MHz. For single exposures, eight groups of mice of differing age, from preweaned to mature, were exposed for 1 hr. For repeated exposures, animals were irradiated 1 hr/day, 5 days/wk, from day 4-7 postpartum for 10 wk. Animals were divided into two equal groups to serve as control and irradiated subjects. Body mass of animals was determined daily for 10 wk from the beginning of RF irradiation, and weekly thereafter. Groups of four mice were placed either in the control or in the radiation chamber at four standard locations. Blood was withdrawn from the tail vessels to make hemograms via micromethods. Formed blood elements were not affected to any significant extent by RF exposure. The comparable increments of body mass of irradiated mice and controls indicated that the animals remained in good health. Necropsy and histopathologic examinations of all organ systems did not reveal changes that could be attributed to radiation, although minute biologic injury at the molecular level could not be discounted.

- 5420 RESPONSE OF LYMPHOCYTES IN VITRO TO 30-MHZ RADIO-FREQUENCY FIELDS (MEETING ABSTRACT). (Eng.) Lovely, R. H.; Sparks, T. J.; Guy, A. W. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 138; 1977: pp. 138; 1977. (0 refs)

Mitogen-stimulated lymphocyte cultures were exposed to 30-MHz radio frequency fields and compared as to mitotic index and blast-cell percentage with non-exposed cultures. No significant differences were observed between exposed and nonexposed cultures. However, the number of successful cultures (cultures containing at least 10⁶ cells with a significant percentage of transformations) was significantly lower in exposed cultures.

- 5421 DIFFERENTIAL EFFECTS OF RF RADIATION ON SUBPOPULATIONS OF MURINE LYMPHOCYTES (MEETING ABSTRACT). (Eng.) Liburdy, R. P. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 139; 1977. (0 refs)

The lymphocyte population in the spleen of mice that exhibited radio frequency (RF)-induced, acute lymphopenia was examined for altered heterogeneity with respect to expression of complement-binding and spontaneous sheep red blood cell (SRBC)-binding surface receptors. Mice that exhibited RF-induced lymphopenia showed a relative enrichment of complement-dependent, SRBC rosette-forming lymphocytes (CRL) and a depletion of spontaneous SRBC rosette-forming lymphocytes (SRL). The relative percentage of splenic CRL in RF-exposed mice was 1.5-fold

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greater than that observed in sham-exposed mice ($32.0 \pm 3.1/20.8 \pm 4.3$, $n = 12$). The relative percentage of SRL in RF-exposed mice was 2.1-fold less than that in sham-exposed mice ($13.1 \pm 2.4/27.3 \pm 5.1$, $n = 12$). In contrast, RF-exposure to 26-MHz fields at reduced intensity (2.5 W/kg specific absorption rate [SAR]), which produced no lymphopenia, also produced no alterations in splenic populations of CRL and SRL. To investigate the effects of RF radiation on peripheral blood lymphocytes (PBL), splenectomized mice were exposed to 26-MHz radiation (26.7 W/kg SAR). The PBL were collected by cardiac puncture and isolated on a Ficoll-sodium metrizoate density gradient. The PBL population showed an increase in CRL and a decrease in SRL that was more marked than that observed in splenic lymphocytes from RF-induced lymphopenic mice. Lymphopenia accompanied by increased splenic CRL and decreased splenic SRL could be induced in quiescent mice by administration of methyl prednisolone sodium succinate. The data suggest that the differential effects of RF-radiation on mouse lymphocytes may be the result of an in vivo release of corticosteroids in response to thermal stress from RF radiation.

5422 CHRONIC EXPOSURE OF RATS TO 425- or 2450-MHZ MICROWAVE RADIATION EFFECTS ON LYMPHOCYTES (MEETING ABSTRACT). (Eng.) Smialowicz, R. J.; Kinn, J. B.; Weill, C. M.; Ward, T. R. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 140; 1977. (0 refs)

Rats were exposed in utero and through 40 days of age for 4 hr/day in a temperature-controlled environment to continuous wave (CW) microwaves either at 2,450-MHz in an anechoic chamber or at 425 MHz (CW) in a transverse electromagnetic mode (TEM) transmission line. The power densities of incident radiation were 5 mW/cm² at 2,450 MHz and 10 mW/cm² at 425 MHz. Specific absorption rates (SAR) for rats of different ages were determined by twin-well calorimetry at each frequency. At 2,450 MHz, SAR values from 1 to 5 mW/g were calculated for pregnant rats and for pups to 40 days of age. For rats exposed to 425 MHz, SAR values between 3 and 7 mW/g were also computed from measurements of forward, reflected, and transmitted power. Rats were sacrificed at 20 and 40 days of age, and blood was obtained for complete blood counts. In addition, the in vitro blastogenic response of blood and lymph node lymphocytes was measured by ³H-thymidine incorporation into DNA following stimulation of the cells with T- or B-lymphocyte mitogens. Exposure of rats at 425 MHz resulted in an absolute neutropenia and a relative lymphocytosis in two of three experiments. Significant increases ($p < .05$) in the response of lymph node lymphocytes to stimulation with phytohemagglutinin (PHA) were observed in irradiated rats. Also, the response of lymph node lymphocytes to B-cell mitogens increased significantly. In animals exposed to 2,450 MHz there were

changes in the mitogen response of both T- and B-lymphocytes from lymph nodes and T-lymphocytes from blood. However, there were no changes in peripheral blood counts after exposure at the higher frequency. The data indicate that chronic exposure of rats to microwaves at either 2,450 MHz or 425 MHz may result in changes in the mitogen-stimulated response of lymphocytes.

5423 ALTERATION OF CELL-MEDIATED IMMUNITY BY LOCAL MICROWAVE HYPERTHERMIA (43°C) OF GUERIN EPITHELIOMA (MEETING ABSTRACT). (Eng.) Szmigielski, S.; Janiak, M. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 141; 1977. (0 refs)

Tumor-bearing rats (Guerin's epithelioma) underwent three 1-hr sessions of localized microwave hyperthermia (LMWH) during wk 3 or 5 after tumor implantation. A rise of temperature in the tumor to 43 ± 0.05 C was accomplished; electrical shielding helped maintain temperatures below 40 C in the remainder of the rat's body. Subsequently, in treatments prescribed by a factorial design, rats were infused with Streptolysin S (SLS) i.p., with *Corynebacterium parvum* (CP) intratumorally, with both agents, or with neither. Eight wk after implantation, the following results were noted: (1) LMWH in 12 rats during wk 3 resulted in three cures and eight tumor regressions; in contrast, treatment of 12 rats during wk 5 resulted in four regressions and no cures; and (2) LMWH, when combined with SLS or CP or both, was even more efficacious in eradicating tumors, especially when administered during wk 3. These data and those from immunologic assays indicate that LMWH is not only a selective killer of cancer cells but acts as a potent immunostimulator.

5424 FURTHER CHARACTERIZATION OF MICROWAVE-INDUCED CHANGES IN SUBPOPULATIONS OF LYMPHOID SPLEEN CELLS IN THE MOUSE WITH PARTICULAR REFERENCE TO COMPLEMENT-RECEPTOR-BEARING LYMPHOCYTES (MEETING ABSTRACT). (Eng.) Wiktor-Jedrzejczak, W.; Ahmed, A.; Leach, W. M.; Czerski, P.; Cyr, H.; Sell, K. W. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 142; 1977. (0 refs)

Exposure of the mouse to 2,450-MHz microwaves results in an increased number of complement-receptor-bearing lymphocytes (CRLs) in the spleen. Further characterization of this effect was investigated through single exposures of CBA/J mice in an environmentally controlled waveguide. An increase of CRLs was observed between day 4 and 10 after radiation, a plateau occurring after day 6. The increase was more pronounced when flow of radiation

proceeded from tail-to-head as opposed to head-to-tail; increased variability resulted when flow was incident on the mouse's sagittal plane. The increase was dose dependent, the strongest response occurring to a dose of 40 J/g (45-min exposure); between 10 and 20 mW/g, the level of CRLs was independent of dose-rate. Amplitude modulation at 12 Hz yielded results that were similar to those obtained with continuous wave radiation. Assessment by a combined, immunofluorescent-rosetting technique revealed that the increased sub-populations were predominantly of CR⁺ and Ig⁺ B-cells. There was also an increase in Fc-receptor-bearing B-cells that was unrelated to changes of number either in theta-positive or in E-rosette-positive T-cells.

- 5425 THE RELATIONSHIP OF THERMAL STRESS TO IMMUNE-SYSTEM RESPONSE IN MICE EXPOSED TO 2.6-GHZ RADIO-FREQUENCY RADIATION (MEETING ABSTRACT). (Eng.) Krupp, J. H. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 143; 1977. (0 refs)

To investigate the relationship of thermal stress to immune-system response, hybrid inbred mice were exposed to 2.6-GHz radio frequency radiation at power densities of 10, 15, and 20 mW/cm² for different periods of time. Sensitization by inoculation with sheep red blood cells (SRBC) was done at various times before and after radiation. Four days after the sensitizing treatment, spleens were harvested and assayed for the presence of plaque-forming cells (PFC) in SRBC films. Increased numbers of PFC occurred whenever the exposure conditions were such as to produce a rise of rectal temperature by 3.0 C. The greatest increase occurred when sensitization followed radiation exposure by 4 hr, coinciding with the peak of a shift in peripheral lymphocyte/leucocyte ratio. Repeated exposures over a week or more did not increase PFC numbers so long as the specific absorption rate (SAR) of any fraction did not exceed that which produced the threshold temperature. The same response could be elicited by the administration of cortisone, which indicates that the observed changes were an adrenal-mediated response to thermal stress. Biologic response as a function of SAR is discussed.

- 5426 A 915-MHZ EXPOSURE SYSTEM FOR HYPERTHERMAL TREATMENT OF CANCER (MEETING ABSTRACT). (Eng.) Johnson, C. C.; Plenk, H.; Durney, C. H. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 149; 1977. (0 refs)

A 915-MHz microwave system for inducing hyperthermia is described. Energy is supplied by a microwave

generator to a rectangular direct-contact diathermy applicator with matching through a double-stub tuner. Approximately 50 W are required to obtain a therapeutic elevation of temperature in deep tissues to the 42-43 C range. The applicator is 13 cm x 13 cm and is fitted with a plastic cover plate through which cool air is blown to control surface temperature. Surface cooling is essential to obtain an optimal temperature profile in the tissues. Experiments were performed on tissues of normal animals to gain experience with requirements for power with the applicator and with thermometry. Animals with spontaneous tumors were treated, and significant regression and necrosis were observed in several cases. The results of preliminary experiments are reported, and resulting design-specifications for a 915-MHz hyperthermia system for cancer treatment are outlined.

- 5427 EXPERIMENTAL AND NUMERICAL STUDIES OF TEMPERATURE IN A HUMAN LEG HEATED BY DIATHERMY (MEETING ABSTRACT). (Eng.) Emery, A. F.; Stonebridge, J.; Sekins, M. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 150; 1977. (0 refs)

A section of the human thigh was modeled by a finite-element thermal analyzer, and the transient elevations of temperature resulting from application of diathermy were computed. Computations were performed for normal application, application with a simultaneous cooling of the skin, and application after pre-cooling of the limb. The aim was to develop a treatment schedule that would yield the desired core temperature while not producing unacceptably high temperatures in other regions of the thigh. Temperatures were measured in subjects undergoing the treatments and were compared to the computations to verify the assumptions used in the computer-model. The results have enabled the establishment of guidelines necessary for efficient diathermy of tissues well below the surface of the thigh.

- 5428 A STUDY OF LEAKAGE FIELDS NEAR THERAPEUTIC 915- AND 2450-MHZ APPLICATORS AS APPLIED TO MODELS AND AS USED IN HUMAN EXPOSURES (MEETING ABSTRACT). (Eng.) Lehmann, J. F.; Guy, A. W.; Stonebridge, J. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 151; 1977. (0 refs)

An XYZ tracking system (controlled by a DDP-516 Honeywell computer) with a National Bureau of Standards EDM-1C high density probe was used to plot the radiation levels in an anechoic chamber. Stray radiation resulting from various contact and noncontact applicators was plotted using models

that were representative of the electrical properties of tissues and were shaped according to human anatomy. The system was calibrated initially by using microwave sources with known theoretic near- and far-zone fields at 915 MHz and 2,450 MHz. The most common types of therapeutic applications were duplicated. For further verification, the same plots were made during exposures of human beings, which were identical to those used in therapy but with low output power for safety. Results obtained with the various applicators in the different types of situations can serve as a guide to the physician who wishes to apply these modalities while avoiding exposure of sensitive organs such as eyes and testes. In addition, this evaluation provides valuable information as to the best technique of application and the most suitable approaches to applicator design.

- 5429 LOCALIZED EMBEDDING OF LABELLED MICROSPHERES BY MICROWAVE HEATING IN TISSUES OF HYPOTHERMIC DOGS (MEETING ABSTRACT). (Eng.) Popovic, V.; Popovic, P. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 152; 1977. (0 refs)

The hind leg of a dog was profoundly cooled while the gracilis muscle of the same leg was kept slightly hyperthermic (37-39 C) by microwave heating (differential hypothermia) to study the preferential embedding of radionuclides. For muscle rewarming, a microwave system was used (S-band: 2,450 MHz) that comprised a 100-W continuous wave magnetron with a coaxial dual-directional coupler to monitor incident and reflected power. The system used dielectrically loaded and tapered wave guides. Labelled microspheres were injected as a bolus into the left ventricle of the heart. The circulation measured by trapping of Technetium (^{99}Tc)-labeled carbonized microsphere in capillaries through the warmed muscle tissues was 5 to 12 times greater than that measured through the cold muscles of the same leg. When differential hypothermia was used to induce selective embedding of Yttrium- ^{90}Y -loaded microspheres in the warm gracilis muscle of the cooled leg, pronounced damage (or even complete destruction) of hyperthermic muscle tissue was observed while leaving undamaged all other muscle tissue that was protected by cooling. It is suggested that differential hypothermia might be useful in the preferential embedding of medical radionuclides whenever a superselective catheterization of tumors or of other tissues is not possible.

- 5430 THE EFFECTS OF HYPERTHERMIA, MICROWAVE RADIATION, AND ASCORBIC ACID ON THE METABOLISM OF EHRLICH ASCITES CARCINOMA CELLS IN VITRO (MEETING ABSTRACT). (Eng.) Plontek, G. E.; Cain, C. A.; Milner, J. A. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The Inter-

national Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 154; 1977. (0 refs)

Ehrlich ascites tumor cells (EATC) were simultaneously incubated in vitro at the same temperature (37.5 or 42.5 C) in either a microwave field (200 mW/cm²) or in a water bath. The differences in release of $^{14}\text{CO}_2$ due to the metabolism of uniformly labeled glucose (U- ^{14}C -Glucose) from the irradiated and nonirradiated EATC were not statistically significant at the 0.01 level at 37.5 and 42.5 C. The presence of 1 mM ascorbic acid in the incubation media markedly stimulated glucose metabolism in EATC. The differences in release of $^{14}\text{CO}_2$ due to the metabolism of U- ^{14}C -Glucose with ascorbic acid versus no ascorbic acid in the incubation media were statistically significant ($p < 0.01$) at 37.5 and 42.5 C in both irradiated and nonirradiated samples. However, the differences in glucose metabolism between irradiated and nonirradiated cells in the presence of ascorbic acid were not statistically significant at either temperature. A number of other labeled compounds were used to characterize further the effects produced by cellular heating and ascorbic acid on EATC metabolism. $^{14}\text{CO}_2$ release from 1- ^{14}C -pyruvate and 1,5- ^{14}C -citrate metabolism were released at specific points in the glycolytic pathway and the trichloroacetic acid cycle, respectively. The release of labeled CO_2 from these compounds was increased significantly in the presence of ascorbate. In addition, cells incubated in the presence of ascorbate had a large decrease in their lactate levels. It has been reported that ascorbate inhibits the enzyme, phosphodiesterase, which in turn inhibits the breakdown of cyclic adenosine monophosphate (AMP) to AMP. Although the mechanism is unclear, cyclic AMP has been shown to inhibit the growth of some tumors in vivo. Since changes in nucleotide levels may be related to tumor growth, future research will determine the effects of cellular heating and ascorbic acid on cyclic AMP and the other adenosine nucleotides AMP, adenosine diphosphate, and adenosine triphosphate.

- 5431 EFFECTS IN VIVO OF COMBINED MICROWAVE AND X-RAY TREATMENT ON A TRANSPLANTABLE MOUSE MAMMARY ADENOCARCINOMA (MEETING ABSTRACT). (Eng.) Clarke, B. J. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 155; 1977. (0 refs)

The effects of microwave- and x-radiation, alone and in combination, on the growth in vivo of mammary adenocarcinoma (BW 10232) of C57 black/6J mice were explored. After tumor transplantation, mice were exposed either to microwaves (91.898 \pm 0.508 mW/g dose rate) or to x-rays (1,000 R) or to both (84.805 \pm 2.49 mW/g dose rate and 1,000 R) for 2 wk. Both the combined treatment and x-rays alone significantly reduced growth of the tumor as compared with the control treatment ($P < 0.01$). However,

the combined treatment was no more effective than x-rays alone in retarding growth. The difference between microwave and control treatments was not significant ($P > .10$). A positive correlation was observed between amount of microwave energy absorbed and tumor mass. Although there were large areas of necrosis in tumors from both microwave- and x-radiated animals, all tumors contained cells that were undergoing mitosis. The in vivo studies indicate that x-rays successfully inhibit tumor growth, while microwaves appear to stimulate tumor growth.

- 5432 COMBINED EFFECTS OF PULSED MAGNETIC RADIATION (DIAPULSE) AND CHEMOTHERAPY ON TUMOR-BEARING MICE (MEETING ABSTRACT). (Eng.) West, B.; Regelson, W. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 156; 1977. (0 refs)

The effect of simultaneous treatment utilizing pulsed radiowaves and cancer chemotherapy on the life spans of BDF₁ mice with Lewis lung carcinoma was investigated. In comparison to non-treated controls, the combination of hydroxyurea and whole-body non-ionizing electromagnetic irradiation (at 27.12 MHz) produced differential enhancement of longevity of 5 and 102%, depending on output power. The higher power (38 root mean square [rms] W) had the greatest effect. The lower power (5 rms W) and the hydroxyurea administered alone did not significantly alter the time-to-death. Hydroxyurea combined with the higher power output (38 mean W achieved by pulsing the radiation 600 times/sec; at a 3.9% duty cycle, peak W=975) produced a mean extension of life 67% greater than that of the group treated with hydroxyurea alone. A second drug, Cytosine, when administered 500 hr after transplanting of tumor, consistently produced significant prolongation of life. A 28% extension of life over that from Cytosine alone resulted from daily exposure at the lower power output (5 mean W, 160 pulses/sec at 490 peak W with a 1% duty cycle) throughout the course of the chemotherapy treatment. A third drug, bleomycin, did not alter life span either alone or in conjunction with non-ionizing irradiation. Further studies are underway with L1210 leukemia and with other anti-tumor agents to determine the consistency of the findings and whether they relate to drug metabolism, thermal effects, or the action of pulsed magnetic fields on the host.

- 5433 THE RESPONSE OF PIG SKIN TO COMBINED X-IRRADIATION AND MICROWAVE HEATING (MEETING ABSTRACT). (Eng.) Field, S. B.; Hand, J. W. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 157; 1977. (0 refs)

To study the response to combined x-irradiation and microwave heating, 2,450 MHz electromagnetic radiation was applied to pig skin via a surface applicator for 1.5 hr at 42 C. The temperature was measured by fine thermocouples, perpendicular to the electric field and was found to be uniform through pigs' dermis. A liquid crystal thermometer was later used as a check. In contrast to data previously obtained with rodents, there was little thermal enhancement on the pig skin. Whether this result is due to a difference between animal species or to different techniques of heating is discussed.

- 5434 DESTRUCTION OF SOLID TUMORS BY HEATING WITH RADIO-FREQUENCY ENERGY (MEETING ABSTRACT). (Eng.) Dickson, J. A. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 158; 1977. (0 refs)

A radio frequency (RF) generator that operates at 13.56 MHz was developed for use in cancer hyperthermia. The apparatus employs the condenser-field technique whereby the tissue is part of the output circuit and is heated between two paddle electrodes that are applied on opposite sides of the tumor. Tuned compensating coils in the handles of the paddles, a connector lead between the paddles, and an inverse direct current feedback loop between the RF output and the crystal oscillator produce stable and readily controlled heating of a tumor. One hundred and eight subcutaneous murine tumors of three different types at various sites and up to 3 cm³ in volume were heated to 45 or 50 C for 15 to 30 min. A regression rate of 100% was seen. Twenty-five intramuscular VX2 tumors (10 to 25 cm³) in rabbits were treated at 47 or 50 C for 15 to 30 min, with a 75% regression rate. There was no damage to normal tissues, and temperature of the skin over these tumors remained 4 to 6 C below that of the tumor during the heating.

- 5435 TREATMENT OF TUMORS WITH 69-CM DIATHERMY (MEETING ABSTRACT). (Eng.) Ollendiek, H. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 159; 1977. (0 refs)

Patients with advanced metastatic carcinoma were treated with an infusion of thymus extract combined with whole-body hyperthermia (41 C) as induced by focally applied 69-cm radiation. The treatments were administered twice a week, and over a period of 4 wk, the duration of hyperthermia was increased from 90 min to 5 hr. Remissions occurred in several patients. In some cases, tumors distal to the site of application of 69-cm radiation regressed. It is concluded that the most important clinical effect of hyperthermia is the immunologic unmasking of the

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tumor cell. Heating of the body appears to facilitate recognition of the tumor cell membrane as an antigen, thereby provoking the production of antibodies. In light of this, the authors propose a new course of cancer therapy in which antibodies from animals previously implanted with homogenates of human tumors would be extracted, separated, and injected into the cancer patient, who would then undergo whole-body hyperthermia.

- 5436 TECHNIQUES AND RESULTS OF USING MICROWAVES AND X-RAYS FOR THE TREATMENT OF TUMORS IN MAN (MEETING ABSTRACT). (Eng.) Joines, W. T.; Noell, T. K.; Miller, L. S.; Woodward, K. T. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 160; 1977. (0 refs)

X-rays and microwaves, alone and in combination, were used to treat six terminal cancer patients. X-rays and microwaves were administered every second day for a total of four treatments. In most cases, the combined treatment led to a total regression of the tumor within ~4.5 wk of the initial treatment. The same microwave heating (43.5 C for 30 min) and x-ray dose (400 rads), when applied separately to other tumors of the same patient, caused a 40% regression of the tumor in about 4.5 wk. Theoretic and experimental data relating to selective heating and depth of penetration in tumors by microwaves indicate that the optimal microwave frequencies for heating cancerous tissue lie in a range that approximates 0.5 to 1 GHz. By using a variable-aperture contact applicator a complete system for automatically controlled microwave heating of cancerous tissue was developed. Heating could be produced for any length of time at a selected location within an accuracy of ± 0.1 C. The temperature was monitored by tissue-implantable thermistor probes that were oriented at right angles to the microwave electric field; sample readings of temperature were made only during 1 msec periods (that occurred every 100 msec) when radiation was not applied. The direct-contact applicator was a double-ridge waveguide horn-antenna that operated in the 0.9- to 4-GHz range. By placing aluminum adhesive tape directly on the surface between the tissue and the horn antenna but leaving an opening that defined the area to be irradiated, the aperture could be adjusted from about 8 by 12 cm to the 17 by 22.75 cm opening of the horn antenna, while maintaining a fairly uniform pattern of heating across the aperture.

- 5437 EFFECTS OF 434-MHZ ELECTROMAGNETIC WAVES ON HUMAN CANCERS (MEETING ABSTRACT). (Eng.) Holt, J. A. G. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee

for URSI, held at Airlie, VA on October 30, 1977. November 4, 1977: pp. 161; 1977. (0 refs)

The effects of whole- or part-body microwave radiation (434 MHz) on the progress of malignant tumors in 380 cancer patients irradiated in the near field were studied. At power levels exceeding 35 mW/cm², the only demonstrable effects were on hemoglobin and male fertility. Changes in pulse rate, blood pressure, and electrolytes occurred proportionately to the degree of whole-body hyperthermia that was induced by radiation and were similar to changes from hyperthermia induced by conventional methods. Microwave radiation had destructive effects on certain bacterial colonies and altered the normal bowel flora. Normal repair processes were not impeded, and no effect on blood clotting and coagulation was observed.

- 5438 PULSED ELECTROMAGNETIC ENERGY IN THE ENHANCEMENT OF BODILY REPARATIVE PROCESSES (MEETING ABSTRACT). (Eng.) Photiades, D. P.; Osamo, N. O. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 162; 1977. (0 refs)

Pulsed electromagnetic waves in the 14-MHz band have been used successfully to potentiate resolution of hematoma and to accelerate healing of wounds experimentally. Clinically, successful short-term remissions were achieved in eight cases of chronic leukemia with energy in the 27-MHz band (Diapulse) without recourse to specific drug therapy.

- 5439 STUDIES OF BLOOD-BRAIN BARRIER PERMEABILITY AFTER MICROWAVE RADIATION (MEETING ABSTRACT). (Eng.) Merritt, J. H. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 164; 1977. (0 refs)

Since reported alterations of permeability of the blood-brain barrier (BBB) by radiofrequency radiation have implications for the safety of man, studies were conducted to replicate some of the investigations. Increased BBB permeation by fluorescein in the rat as a result of microwave irradiation at low power densities (2 mW/cm² continuous wave or 0.2 mW/cm² root mean square (rms) for pulsed radiations) has been demonstrated. Alterations in the uptake of ¹⁴C-labeled saccharides of small molecular weight across the BBB of rats also have been reported. An attempt to replicate the fluorescein study was not successful. The study was extended to include chemical assay of fluorescein in the rat's brain after animals were radiated by pulsed 1.2-GHz microwaves at power densities to 38 mW/cm² rms. Compared with controls, there was no significant increase in fluorescein in any area of the brain. Animals were also heated in a warm-air

oven or by microwave radiation to achieve a change of brain temperature of 4 C. Under these conditions an increase in permeation of the blood-brain barrier by fluorescein was observed. A study on brain uptake of ^{14}C -labeled saccharides at the previously reported parameters of microwave irradiation also failed to confirm the original finding of increased permeability. The data gathered from three separate experiments on rats that were radiated at 1.2 GHz indicate that hyperthermia of the brain is necessary for inducing permeation of blood-brain barrier by large or small molecules. The results are discussed in the context of safety standards for nonionizing electromagnetic radiation

5440 EFFECTS OF MICROWAVE-INDUCED HYPERTHERMIA ON THE RAT BLOOD-BRAIN BARRIER (MEETING ABSTRACT). (Eng.) Sutton, C. H. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 165; 1977. (0 refs)

The effects of microwave radiation at 2,450 MHz on the blood-brain barrier were investigated in rats. Horseradish peroxidase, a basic enzymatic protein, was used as a tracer and was injected intravenously before heating of the brain by microwaves. After heating, rats were sacrificed by aortal perfusion with iso-osmotic saline at a temperature of 4 C. Homogenates of brain were then assayed for residual peroxidase activity, which was used as an indicant of disruption of the blood-brain barrier. Heads of rats were heated by microwave radiation to 37, 40, 42, or 45 C for periods of 10, 15, or 30 min, while the animals' bodies were shielded with Eccosorb microwave-absorbing material. After 10 min, there was residual peroxidase activity in brain at 45 C, indicating disruption of the barrier. There was similar disruption after heating to 42 C for 15 min. To preserve the integrity of the blood-brain barrier and to permit the brain to be heated safely for longer periods, the brain's tolerance to microwave radiation was compared to normothermic (37 C) and to hypothermic (30 C) rats. In addition to an increase of survival time, body-core hypothermia protected integrity of the barrier for 15 and for 30 min at 45 and 42 C, respectively. When brain temperature was maintained at 40 C, the protective effect of body-core hypothermia was most pronounced. Barrier integrity was lost after 45 and 60 min of irradiation in normothermic rats but remained intact for 2 to 3 hr in hypothermic animals. It is concluded that microwave radiation is capable of disrupting the blood-brain barrier. The brain's tolerance to microwave is dose-related, depending both upon the elevation of temperature and upon duration of elevation.

5441 REVERSIBILITY OF THE BLOOD-BRAIN BARRIER (MEETING ABSTRACT). (Eng.) Albert, E. N. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*.

Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 166; 1977. (0 refs)

The reversibility of microwave-induced changes in the permeability of the blood-brain barrier was investigated in Chinese hamsters irradiated with 2,450-MHz microwaves at a power density of 10 mW/cm². Appropriate sham-irradiated controls were used for comparison. After irradiation treatment, all animals were allowed to recover for periods to 2 hr and then were injected with 10 mg of horseradish peroxidase via the femoral vein. Two to 5 min after injection the animals were perfused with glutaraldehyde and then were dissected, sliced, and treated with 3-3' diaminobenzidine. Gross and microscopic examination of incubated sections revealed that after 1 hr of recovery there was a decrease in the permeability of the blood-brain barrier as compared with sections from animals sacrificed immediately after irradiation. However, there was little leakage of peroxidase in brains of animals that were sacrificed after a 2-hr period of recovery. These observations indicate that a partial restoration of the blood-brain barrier's impermeability may have occurred within an hour of irradiation and virtually complete restoration within 2 hr. These conclusions are limited to passage of molecules of the size and properties of horseradish peroxidase (molecular weight 40,000), e.g., proteins, such as, serum albumins.

5442 DETERMINANTS OF BRAIN UPTAKE (MEETING ABSTRACT). (Eng.) Oscar, K. J. In: *Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves*. Sponsored by The International Union of Radio Science & The U.S. Committee for URSI, held at Airlie, VA on October 30, 1977-November 4, 1977: pp. 167; 1977. (0 refs)

The implications of microwave-induced central nervous system alterations and the extent to which changes of permeability may explain recently reported effects of microwave irradiation at low power densities are discussed. The blood-brain exchange of proteins, electrolytes, and large water-soluble non-electrolytes is restricted due to a continuous layer of cerebro-vascular endothelial cells that are characterized by tight junctions and a scarcity of pinocytotic vesicles for transport. Microwave-induced changes in brain distribution and uptake of blood-carried substances have been reported in work performed on rats, Chinese hamsters, and rabbits. Horseradish peroxidase, sodium fluorescein, radiolabeled saccharides of varying molecular weights, and labeled dibasic phosphate salt have all exhibited increases in blood-brain exchange. There are indications that these alterations are reversible, which may indicate changes in tight-junction integrity or pinocytotic transport rather than cell-membrane destruction. The blood-brain barrier (BBB) has been similarly opened reversibly by treatments involving convulsions, cerebral concussions, hypercapnia, acute hyper-

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tension, ionizing radiation, and infusion with hypertonic solutions. Many of these conditions alter the autoregulation of blood flow, which may cause widening of tight junctions by endothelial-cell shrinkage or capillary dilatation. Investigators of effects of microwave irradiation on brain uptake have used several different techniques of measurement and observation including optical-, ultraviolet-, and electron-microscopy, chemical assay, single-radioisotopes, and double radio-labeled

indicators with highly diffusible reference substances as a ratio standard. Most of these techniques measure the net influence of several variables on brain uptake; these techniques do not differentiate the effects of changes in the vascular space, alterations of blood flow, and changes of BBB permeability. These BBB investigative techniques as well as others (e.g., dual compartment analysis) are discussed with emphasis on how each may affect interpretation of results.

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